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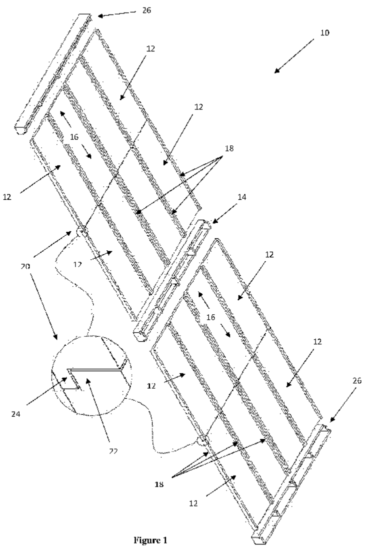

Figure 1

(57) Abstract: Improvements in apparatus and methods for the rearing of abalone in both on-shore and off-shore environments. An on-shore tank for growing abalone comprising an elongate base comprising, a plurality of prefabricated base portions, upright walls parallel to a longitudinal axis of the elongate base, a plurality of channels, connected to a water discharger for delivering a flow of water to each channel and a water drain, a plurality of tanks being arranged into an array. An offshore submersible container defining an enclosure for abalone, the enclosure comprising an internal surface for receiving abalone thereon, one or more apertures configured to allow water to flow through the enclosure when the container is submerged, but not to allow abalone to pass therethrough, one or more feeding ports in the container walls, and one or more feed dispensers, each dispenser comprising a receptacle for abalone feed and a mouth portion that is configured for receipt at a respective feeding port.

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ABALONE FARMING APPARATUS AND METHODS

Technical Field

[0001] The present invention relates to abalone farming apparatus and methods. In particular, the present invention relates to improvements in apparatus and methods for the rearing of abalone in both on-shore and off-shore environments.

Background Art

[0002] Abalone is a highly prised food, with its worldwide demand constantly increasing. In order to meet this ongoing demand, abalone farms have been established to supplement the dwindling supply of wild catch abalone. The vast majority of abalone farms are land-based only, although some final grow-out off-shore farms now exist.

[0003] In existing abalone farms, after spawning, abalone larvae are typically caused to settle on the surfaces of plastic plates on which algae has been grown. The plates are then spaced apart in racks and nested within a tank for about 5-6 months, or until they grow to a size of about 10mm. Factors such as exposure to sunlight are carefully controlled during this “plate rearing” stage in order to balance the growth of algae on the plates with abalone growth. The juvenile abalone are then moved to so-called “Slab tanks”, where they are grown in shallow tanks through which high quality sea water constantly flows. The abalone are fed a manufactured diet which is specially formulated for the different production stages and, during the first 5-7 months in the slab tank, grow from about 10mm to about 25mm in size. Finally, about three years after spawning, abalone having a diameter of about 90 mm are ready for market and are removed from the slab tank for processing.

[0004] Existing abalone farms require extensive infrastructure such as buildings, tanks, pumping systems, etc., and are therefore very costly to operate. Indeed, it has been estimated that at current electricity rates, producing about 200 tonne of farmed abalone costs in the region of one million Australian dollars. Furthermore, growing abalone to a marketable size takes about 3 years and currently requires extensive tank infrastructure for almost all of that time. As such, existing abalone farms typically face production limits of about 200 tonnes per year per, and are therefore unlikely to be able to meet the growing worldwide demand for abalone.

[0005] Expansion of traditional abalone farms to meet this demand is not without its problems. For example, construction of the required large concrete tanks and their associated water supply and draining systems is expensive and time consuming, and can often be complicated by factors

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such as uneven or unstable ground, existing buildings or infrastructure (which can hinder a concrete pour), etc. Furthermore, the water supply and drain systems may be complicated to operate and prone to malfunction.

[0006] Off-shore farms in which abalone are finished are known. In such farms, once the abalone have been grown above a certain size on-shore (typically about 50mm), they are transferred to an off-shore growing facility where they are housed, for example, in a net suspended from floats (typically, the net is suspended from a circularly-shaped float). A number of structures are located in the net, which provide hides for the abalone and surfaces upon which they can reside (the abalone will not reside on the net).

[0007] Whilst such off-shore farms may be less infrastructure-dependent than the on-shore farms described above, they still suffer from a number of problems. For example, food for the abalone is broadcast into the enclosure, whereafter it falls through the water column and settles on the surfaces of the hides for the abalone to eat. As would be appreciated however, a significant proportion of the food may simply fall through the net and hence not be accessible to the abalone, thereby increasing the cost of production or reducing the rate of growth of the abalone. Movements in the water column may also cause food that did settle on the hides to be swept off before the abalone can eat it. Finally, there is an ever-present risk of predators being able to get through the net and eat the growing abalone.

[0008] Off-shore abalone farms must also typically be anchored reasonably securely to the seafloor so as to minimise the risk of damage during storms or in rough seas. The location of the farm in the water is therefore fixed, which might cause environmental problems associated with reducing the amount of sunlight received by the seabed underneath the farm, or by polluting the area surrounding the farm with the food not able to be eaten by the abalone.

[0009] Off-shore farms that use specifically designed submergible abalone-holding containers are known. However, the supply of feed to and the periodic inspection of the abalone in such containers is difficult, and would usually require divers and/or other specialised equipment.

[0010] It would be advantageous to improve abalone farming apparatus and methods such that the productivity of abalone farms can be increased to meet the growing worldwide demand for abalone.

Summary of the Invention

[0011] In a first aspect, the present invention provides a tank for growing abalone. The tank comprises an elongate base comprising upright walls that are arranged substantially parallel to a longitudinal axis of the elongate base, and which define a channel therebetween for receiving a

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flow of water. The elongate base comprises a plurality of prefabricated base portions adapted to be sealingly connected together and a width of the elongate base is defined by a width of one of the prefabricated base portions.

[0012] As would be appreciated, constructing an abalone-rearing tank (e.g. a slab tank) from prefabricated base portions can significantly simplify the construction process over prior art processes. Such a modular tank would not require much of the preparation traditionally associated with a large concrete pour (for example), and a crane or the like could be used to deliver the prefabricated base portions to the site, even around existing infrastructure (e.g. sheds and other slab tanks). Furthermore, precast portions may be manufactured off-site and in a more controlled environment than could be achieved on-site, and should therefore have a significantly higher and more consistent quality.

[0013] In some embodiments, the plurality of prefabricated base portions may be substantially identical to one another in order to even further simplify the assembly process and reduce the number of different components required to construct the tank.

[0014] In a second aspect, the present invention provides a prefabricated base portion adapted to be used in the tank of the first aspect of the present invention.

[0015] In a third aspect, the present invention provides a tank system comprising a plurality of the tanks of the first aspect of the present invention, the plurality of tanks being arranged in an array.

[0016] In some embodiments of the third aspect, the tank system may comprise two tanks arranged in-line along the longitudinal axis of their elongate bases and with an end of one tank positioned adjacent to an end of the other tank (i.e. in a “head to head” arrangement). The tank system may also comprise a central trough, which may be located between and sealingly connected to the elongate bases of the adjacent ends of the tanks, and be selectively operable to either deliver a flow of water into the channels of the tanks or to drain water delivered into distal ends of the channels of the tanks. In such embodiments, the amount of infrastructure (e.g. water piping and pumping apparatus) required to operate the tank system can be minimised, thereby reducing the complexity and costs (both operating and set-up) of the tank system.

[0017] The tank system may, in some embodiments, further comprise an elevated platform above the central trough which, in some embodiments, may be adapted to receive a water receptacle thereon. The water receptacle may be operable to deliver a water surge into one or more of the channels in order to flush clean the channel(s) in a similar way that a wave would do in the abalones’ natural environment.

[0018] In some embodiments, the water receptacle may be slid along rails provided on the elevated platform such that it is in alignment with a selected one or more of the channels in the tank system. In some embodiments, the water receptacle may be pivotable towards either tank such that the water surge may be delivered to a selected channel(s). In this manner, the water receptacle may be easily repositioned and pivoted (manually or automatically) in order for it to progressively flush clean all of the channels in the tank system.

[0019] The tank may, in some embodiments, further comprise an abalone feeding apparatus that is adapted to move along a length of each channel and broadcast food into the channel. The feeding apparatus may, for example, slide along rails provided on the upright walls.

[0020] The tank may, in some embodiments, further comprise a dual water supply. As would be appreciated, failure of a water supply (for even a short period of time) could lead to mass abalone mortality.

[0021] In some aspects of the present invention, a tank or tank system for growing abalone is provided that comprises an elongate base comprising upright walls which define a channel therebetween for receiving a flow of water, wherein the tank or tank system further comprises any one or more of the following:

a plurality of prefabricated base portions adapted to be sealingly connected together;

a central trough located between and sealingly connected to the ends of adjacent elongate bases, and selectively operable to either deliver the flow of water into each channel or to drain water which has been discharged into each channel at distal ends of the adjacent elongate bases;

an elevated platform adapted to receive thereon a water receptacle that is operable to deliver a water surge into one or more of the channels; and

an abalone feeding apparatus that is adapted to move along a length of each channel and broadcast food into the channel.

[0022] Also disclosed herein is a submersible container for holding abalone. The container comprises container walls that define an enclosure for abalone, with the enclosure comprising an internal surface for receiving abalone thereon. The container also comprises one or more apertures configured to allow water to flow through the enclosure when the container is submerged, but not to allow abalone to pass therethrough. The container also comprises one or more feeding ports in the container walls and one or more feed dispensers. Each dispenser comprises a receptacle for abalone feed and a mouth portion that is configured for receipt at a

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respective feeding port, wherein the one or more dispensers are independently operable to dispense feed contained therein into the enclosure.

[0023] Such a container is well-suited for use in off-shore environments, for example those where the container is suspended from a float or a long line. The natural movement of water causes a flow of water through the container, which provides the abalone residing on the internal surfaces with a constant source of oxygenated water, without all the requirements of on-shore growing facilities such as slab tanks and constant water pumping.

[0024] Furthermore, providing feed dispensers with the submersible container can advantageously extend the time between inspections of the abalone in the container. Although one should always inspect the growing abalone on a regular basis, in such embodiments, the time between inspections can be extended (e.g. by as much as a month). This is a significant improvement over some existing submersible containers, which either need to be retrieved from the water every week or so to replenish the abalone's feed, or require divers to couple hoses via which abalone feed can be pumped from a boat into the container.

[0025] In some embodiments, the one or more dispensers may be independently operable to dispense feed contained therein into the enclosure at a predetermined time. In some embodiments, for example, the container may comprise two or more feed dispensers, the plurality of feed dispensers being adapted to dispense feed contained therein into the enclosure at different times (e.g. at different predetermined times). Such embodiments can advantageously ensure a more consistent delivery of food, which may help to prevent food wastage.

[0026] In some embodiments, the enclosure may be configured to receive a member therein, the member providing an additional internal surface for receiving abalone thereon. As the number of abalone which can be held within the enclosure is dependent on factors including the amount of available surface area, increasing the internal surface area means that more abalone can be grown in the container.

[0027] In some embodiments, the member may be substantially planar, which will be helpful when removing abalone because there are no tight corners where they might hide. As would be appreciated, however, it is desirable to maximise the internal abalone-receiving surface area by as much as possible. As such, members that are larger than the enclosure may be used, when the member is foldable to fit within the enclosure. In some embodiments, the member may be foldable a plurality of times in order to define a plurality of additional internal surfaces for receiving abalone thereon. Abalone numbers can therefore be maximised for a given volume, helping to even further improve the efficiency of the farming process.

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[0028] In some embodiments, the container walls may comprise inner and outer walls, with a cavity therebetween. The cavity may, for example, be adapted to receive air, water or sand (or a combination thereof) in order to adjust a buoyancy of the container.

[0029] In some embodiments, the container may be openable in order to access abalone in the enclosure. Removing abalone from a surface can be difficult, and even more so if the abalone are able to hide in recesses that are difficult to reach. Thus, anything that can be done to improve access to abalone in the container would help to improve the efficiency of the farming process.

[0030] Also disclosed herein is a feed dispenser for use with the submersible container of the fourth aspect of the present invention. The feed dispenser comprises a receptacle configured to hold feed for abalone, a mouth portion configured to be received in one of the feeding ports of the container, and a gate that is moveable from a closed position into an open position upon receipt of a signal (e.g. a signal generated at the end of a predetermined time or a signal generated by an external source). Feed contained in the receptacle is dispensed into the enclosure when the gate moves from its closed position into its open position.

[0031] Also disclosed herein is a method for growing abalone in an off-shore location. The method comprises deploying one or more of the submersible containers of the fourth aspect of the present invention on a long line that is anchored to the floor of the ocean, and periodically retrieving each of the one or more submersible containers and inspecting abalone contained therein (e.g. for predators, expected growth, any mortality, etc.).

[0032] Using an off-shore location to rear juvenile abalone would free-up on-shore tank infrastructure for the next round of abalone rearing, thereby reducing the costs associated with long-term usage (up to 3 years) of large tank infrastructure and enabling more generations of abalone to be grown. Furthermore, there is no need to actively pump seawater through the submersible containers (i.e. as is required in on-shore slab tanks) because of the natural movement of water around the container, which significantly reduces costs (per abalone grown) associated with operating pumping systems. Furthermore, the containers of the present invention, especially when held in a suspended environment can significantly reduce predation by keeping the abalone out of reach of bottom feeders such as starfish and the like.

[0033] In embodiments where the submersible container incudes a feed dispenser, the method of the present invention may further comprise exchanging any empty feed dispenser with a full feed dispenser.

[0034] In some embodiments, one or more submersible containers may be retrieved using a retrieval apparatus which overhangs the side of a boat. The retrieval apparatus may, for

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example, be operable to lift the container out of the water, locate the container on a deck of the boat for inspection of abalone contained therein, and subsequently return the container to the water. In such embodiments, the abalone are able to be accessed by personnel on a vessel, with divers not being necessary.

Brief Description of the Drawings

[0035] Embodiments of the present invention will be described in further detail below with reference to the accompanying drawings, in which:

[0036] Figure 1 shows a perspective, partially exploded, view of a tank system in accordance with an embodiment of the present invention;

[0037] Figure 2 shows a cross sectional side view of a trough for delivering water to, or draining water from, a channel of a tank in accordance with an embodiment of the present invention;

[0038] Figure 3 shows a perspective, partially exploded, view of the trough and tank of Figure 2;

[0039] Figure 4 shows a perspective, partially exploded, view of a central trough of a tank system in accordance with an embodiment of the present invention;

[0040] Figure 5 shows a cross sectional side view of a central trough of a tank system in accordance with another embodiment of the present invention;

[0041] Figure 6 shows a perspective exploded view of tank system in accordance with another embodiment of the present invention;

[0042] Figure 7 shows an embodiment of a water supply system for use with a tank system in accordance with an embodiment of the present invention;

[0043] Figure 8 shows an array of tanks in accordance with an embodiment of a tank system of the present invention;

[0044] Figure 9 shows a perspective view of a submersible container for holding abalone;

[0045] Figure 10 shows a perspective view of a plurality of submersible containers for holding abalone, in a stacked arrangement;

[0046] Figure 11 shows a cross sectional side view of the submersible container of Figure 10, in which a member for receiving abalone thereon is contained within the enclosure;

[0047] Figure 12 shows a perspective view of the container and member of Figure 11, in which the container is in an open configuration;

[0048] Figure 13 shows a member for receiving abalone thereon;

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[0049] Figure 14 shows a perspective view of a feed dispenser for use with the submersible container, in which the lid is in a closed configuration;

[0050] Figure 15 shows the feed dispenser of Figure 14 but with the lid in its open configuration;

[0051] Figure 16 shows a perspective view of the feed dispenser of Figure 14 from its other end;

[0052] Figure 17 shows a cross-sectional view of the feed dispenser of Figure 14;

[0053] Figure 18 shows a cross-sectional view of the feed dispenser of Figure 14 after its insertion into a submersible container for holding abalone;

[0054] Figure 19 shows a side view of a plurality of submersible containers for holding abalone deployed off-shore on a long line;

[0055] Figure 20 shows a close up view of a portion of the long line of Figure 19;

[0056] Figure 21 shows a perspective view of a boat being used to retrieve the submersible containers of Figure 19 for inspection; and

[0057] Figure 22 shows a rear view of the lifting apparatus of the boat shown in Figure 21.

Description of Embodiments

[0058] The present invention relates to apparatus and methods which can be used to improve the efficiency of abalone farms, both on- and off-shore. The present invention will be described in further detail below.

<u>Tanks and tank systems</u>

[0059] In one aspect, the present invention provides a tank for growing abalone. The tank comprises an elongate base comprising upright walls arranged substantially parallel to a longitudinal axis of the elongate base, and which define a channel therebetween for receiving a constant (in use) flow of water therethrough. The elongate base comprises (and, in some embodiments, is defined by) a plurality of prefabricated base portions adapted to be sealingly connected together. In another aspect, the present invention provides a tank system comprising a plurality of these tanks, the plurality of tanks being arranged in an array. In yet another aspect, the present invention provides prefabricated base portions for use in these tanks or tank systems.

[0060] As discussed above, abalone farming traditionally includes a slab tank rearing stage where the abalone are grown from juveniles into a marketable size. Such slab tanks are typically long shallow concrete tanks about 18 metres long, 2.5 metres wide and 20cm deep. In order to create a suitable growing environment, about 3 litres of fresh seawater per second is pumped

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through the tank, with a depth of about 75mm of water (enough to cover abalone in the tank) being maintained.

[0061] The tank of the present invention includes an elongate base having upright walls which define a channel for receiving a flow of water therebetween. The elongate base may have any suitable length (e.g. between about 10 and 30 meters or between about 15 and 25 meters) but, similar to traditional slab tanks, is preferably about 18 m long. Trials and experiments have shown that oxygen concentrations in water flowing through slab tanks containing abalone tend to drop below an ideal level after about 18m. Thus, tanks having a length of about 18 meters substantially prevents deoxygenated water from flowing across abalone at the distal end of the tank.

[0062] The elongate base may include any number of channels. Typically, the elongate base comprises a plurality of channels so that the number of abalone that can be grown in the tank is maximised. Each of the channels may have any suitable width (e.g. between about 1 and 5 meters or between about 2 and 4 meters), with the tank having a corresponding width. Similar to the channels provided in the traditional slab tanks, however, the channel width is preferably about 2.5 m. When the elongate base has a plurality of channels, the channels may have the same or different widths. In a specific embodiment, the or each channel is about 18 m long and about 2.5 m wide.

[0063] The upright walls are arranged substantially parallel to the longitudinal axis of the elongate base and may be of any suitable height. For example, in some embodiments, the upright walls may be about 20cm high, as is the case for traditional slab tanks. Typically, the upright walls extend for substantially the entire length of the elongate base, although some under- or over-hang may provide advantages such as those discussed below. The upright walls may have any suitable thickness (i.e. width), provided that they are fit for the purposes described herein. Too narrow and their structural integrity may be compromised during construction of the tank or during subsequent operation. Too thick and they require excess material to form and also reduce the width of the abalone-containing channels, and unnecessarily increase the overall weight of the elongate base. Upright walls having a width of about 150 mm have been found to be effective.

[0064] Any number of prefabricated base portions may be used to form the elongate base (and hence tank) of the present invention. The elongate base may, for example, include two or more prefabricated base portions sealingly connected together in a side-to-side manner in order to provide a wider tank having additional channels. The elongate base may, for example, include two or more prefabricated base portions sealingly connected together end-to-end in order to provide longer channels, or to enable the use of shorter prefabricated base portions.

[0065] In specific embodiments, the elongate base is one or two prefabricated base portions wide. In specific embodiments, the elongate base is two prefabricated base portions long. This configuration has been found to provide a good balance between tank size and relative ease of construction, due to the prefabricated base portions being of a size that is readily transportable and manoeuvrable into position using conventional vehicles and machinery.

[0066] Given the traditional length and width of slab tanks, in such embodiments it may be convenient to provide prefabricated base portions having a length of about 9 m. Two of such base portions may be combined in order to provide channels that are about 18m long. Such prefabricated base portions are of a length that is readily transportable from its place of manufacture to an abalone farm using conventional transport. Such embodiments provide a balance between factors such as a tank ideally having a minimum number of base portions but still being of a useful size, whilst the prefabricated base portions are still capable of being relatively easily transported and subsequently positioned on-site.

[0067] As channels in traditional slab tanks are about 2.5 m wide, the prefabricated base portions may include up to four channels and still be transported using conventional vehicles and machinery. However, prefabricated base portions two channels wide may be preferred in some situations because they may be simpler to handle. A prefabricated base portion having two channels will have a width of about 6 m which, as discussed above, is of a size that is capable of being transported using conventional transport. A prefabricated base portion having four channels will have a width of about 11 m which is (just) of a size that is capable of being transported using conventional transport, but would be heavier and more unwieldy, and hence less suitable for some applications.

[0068] The floor of the channels may be substantially smooth or may include raised members onto which abalone tend to like to position themselves. Such raised members provide refuge for the abalone and simulate a more natural living environment. Whilst the raised members may have any form and orientation, a substantially linearly-shaped raised member that extends substantially parallel to the length of the channel (i.e. substantially parallel to the longitudinal axis of the elongate base) may be easier to remove abalone from when it is time to collect abalone in the tank.

[0069] The prefabricated base portions may be manufactured from any suitable material. In some embodiments, the prefabricated base portions are manufactured from concrete. As would

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be appreciated, concrete is an especially suitable material for applications such as this due to its strength, durability, UV-light resistance and relatively low cost. Other suitable materials include suitably strong and durable plastics (e.g. moulded plastics).

[0070] In embodiments where the prefabricated base portions are manufactured from concrete, the concrete must be of a thickness that imparts a strength sufficient for the base portion to be able to withstand lifting during construction and assembly of the tank or tank system and, subsequently, the weight of the abalone and water flowing through the channels. The floor of the base portion may, for example be at least 100 mm think, at least 130 mm thick or at least 150 mm thick, depending on factors such as the relative size of the base portion and resultant tank, the amount of abalone to be grown in the tank, etc. Similarly, the upright walls (and other prefabricated components described herein) must have a thickness commensurate with its end use.

[0071] In order to simplify construction of the tank or tank system, the plurality of prefabricated base portions may be substantially identical to one another. A reduced number of component parts is another factor that might help to reduce manufacturing costs. In alternative embodiments, however, each of the prefabricated base portions may be the same or different to one another, provided that they can be sealingly connected together in order to form the elongate base.

[0072] The prefabricated base portions are adapted to be sealingly connected together. Any method via which a substantially watertight seal may be formed between connected base portions may be used. For example, in some embodiments, an end of one of the prefabricated base portions may comprise a protrusion configured to be sealingly received at a corresponding recess at an end of another of the prefabricated base portions. Such an arrangement may be provided in the form of an overhanging protrusion configured to reside on a corresponding underhanging protrusion of the adjacent portion. Alternatively, a tongue in groove type structure may be used.

[0073] If the surfaces of the base portions that make the seal are sufficiently smooth, because of the relatively heavy weight of one base portion bearing on the other, then no sealant may be required. In some embodiments, however, a sealant may be used to improve the water tightness of the seal between the base portions. Any water resistant sealing material may be used as a sealant, and especially a material which has some degree of compressibility. Suitable sealants include, for example, silicon-based sealants.

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[0074] In some embodiments, the prefabricated base portions may be constructed with piping and other components *in situ* (e.g. cast into a concrete base portion). Providing plumbing (etc.) for the tanks and tank systems inside the base portions has the potential to significantly simplify construction of the tank, as well as significantly reduce the likelihood of leakage occurring (e.g. because exposed piping gets damaged or is incorrectly aligned, etc. during installation).

[0075] The tanks and tank systems of the present invention may also include additional components which enable the flow of water through its channels. Examples of such components will be described below.

[0076] In some embodiments, an end of the elongate base may be adapted to be sealingly connected to a water discharger for delivering the flow of water to the or each channel. In some embodiments, the other end of the elongate base (i.e. its distal end) may be adapted to be sealingly connected to a water drain. In this manner, a tank capable of providing a flow of water over abalone in its channels may be relatively easily constructed using additional modular components. In some embodiments, the prefabricated base portions may include the necessary features for connecting the elongate base to the water discharger and drain (e.g. tabs and complimentary recesses). Alternatively, these features may be provided separately from the prefabricated base portions.

[0077] The water discharger may, for example, include a trough which extends across a width of the elongate base, and where water delivered into the trough subsequently flows into the or each channel. The water drain may, for example, include a trough which extends across a width of the elongate base, and where water that has flowed through the or each channel drains into the trough. Troughs which extend across a width of the elongate base can deliver a relatively even flow of water through each channel in the tank.

[0078] The elongate bases may be sealingly connected to the water discharger and water drain using any suitable mechanism, for example, as is discussed above in the context of sealingly connecting the base portions. Typically the water discharger and water drain will be substantially the same width as the elongate base, although they may, in some embodiments, be longer or shorter than the width of the elongate base, provided that water is not able to leak from the tank.

[0079] The water discharger and water drain may be constructed from any suitable material, such as concrete or plastic. Whilst the water discharger and water drain would typically be provided in prefabricated form (i.e. along with the prefabricated base portions) for consistency with the modularity of the tank, it is noted that they might, in some embodiments, be separately

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constructed on-site (e.g. after delivery of the prefabricated base portions and set-up of the tank's elongate base).

[0080] The troughs of the water discharger and water drain may have the same structure or a different structure. In some embodiments, one or both of the troughs have a first edge and a second edge, with the first edge being adapted to sealingly connect to the end of the elongate base. The first edge is lower than the second edge, and water introduced into the water discharger trough therefore spills out on that side of the trough and hence into the channels, rather than over the second edge. Similarly, water that drains from the channels into the water drain trough (i.e. over its first edge) cannot spill over its (higher) second edge, and is instead caused to flow into a drain (described below).

[0081] In some embodiments, the water discharger and the water drain may be provided in a form where their function is able to be switched. That is, the water discharger (e.g. a trough at one end of the elongate base) may be switched such that it becomes the water drain whilst, at the same time, the water drain (e.g. a trough at the distal end of the elongate base) is switched such that it becomes the water discharger. Such switching enables the direction of flow of water within the channel(s) to be alternated, simulating tidal flow and assisting in the feeding and oxygenation of the abalone, regardless of their location in the channel (abalone at one end of a channel will go from receiving the least-oxygenated water to receiving the most oxygenated water).

[0082] The tank may be mounted on the ground (or any other surface) in any suitable manner. Existing slab tanks, for example, are typically in the form of concrete slabs formed by pouring concrete into formwork appropriately positioned on the ground. Such tanks, however, may end up being uneven (which would cause problems with water flow, etc.), or may crack due to subsequent earth movements. Thus, whilst the tanks of the present invention can be located on the ground, they may also be adapted to be mounted to one or more piers (e.g. the tanks may include recesses etc. into which the piers can be received). The piers can be arranged before delivery of the prefabricated base portions such that they will support the base portions at a prepared level whilst they are joined to form the elongate base and hence the tank. The prefabricated base portions may, for example, be craned directly onto such piers upon delivery. As would be appreciated, such a method of construction does not require the laying of foundations, thus potentially even reducing the cost of construction of the tank or tank system.

[0083] Also advantageously, the use of piers would enable the elongate base (etc.) of the tank/tank system to be in a raised position off the ground. Such a raised position may be more ergonomic for workers, because they would not need to bend or squat down to ground level in

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order to manually handle material in the channels etc. In effect, the tanks are at a convenient working height for the workers. Furthermore, the plumbing associated with the delivery to and draining of water from the channels may be located above ground (typically on top of the ground), instead of having to be buried underneath the ground in order to have a sufficient drop (as would be the case for tanks located on the ground). As would be appreciated, not only would this reduce the amount of work required to install the tanks of the present invention (e.g. there would be no need to dig trenches for underground plumbing), but also any leakages in the plumbing would be far easier to detect and fix. General maintenance of the plumbing is also greatly simplified if it is not buried.

[0084] In some embodiments, the piers may be adapted such that the distance they project out from the ground is adjustable. Screw piers, for example, are screwed into the ground and, once screwed securely into the ground, can be screwed up or screwed down to adjust their relative heights. Such screw piers may help to significantly reduce the construction time of the tank system, and result in less material being required.

[0085] The piers onto which the base portions are mounted can also be used to support the water discharger and water drain described above.

[0086] In an embodiment of the tank system of the present invention, the tank system comprises a central trough and two tanks that are arranged in-line along the longitudinal axis of their elongate bases and with an end of one tank positioned adjacent to an end of the other tank. The central trough is located between and sealingly connected (e.g. in the manner discussed above) to the ends of the adjacent elongate bases, and is selectively operable to either deliver the flow of water into (one or more of) the channels, or to drain water delivered into (one or more of) the channels at distal ends of the adjacent tanks (i.e. to enable the reversal of water flow through the channels, as described above). As would be appreciated, this embodiment of the tank system could be applied to any even number of tanks (e.g. tanks arranged side-to-side and end-to-end with the central trough between them).

[0087] The array of tanks in this embodiment is advantageous because providing a central trough can reduce the total number of components required to operate the tank system. Further, the footprint of two tanks arrayed in this manner is less than that of two tanks if arrayed separately, which may be advantageous in locations where space is limited.

[0088] The central trough may have the same features as the water discharger and the water drain described above, although both of its edges may need to have similar heights (assuming that the adjacent tanks are at the same level).

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[0089] The tank system (or, indeed, a slab tank system having tanks that are not formed from prefabricated base portions) may also include an elevated platform above the central trough. The elevated platform may be adapted to receive a water receptacle thereon, where the water receptacle is operable to deliver a water surge into one or more of the channels. Such a water surge is similar to waves that occur in the abalones' natural environment, and can be used to both clean out the channels as well as to cause the abalone to develop more muscle mass. Further, the periodic flushing of the channels may assist with oxygenation and feeding of the abalone. As each tank (or even each channel) may have a separate supply and drainage of water in order to help prevent cross-contamination, the receptacle may be adapted to cause water surges isolated to a separate tank or channel.

[0090] The water receptacle may be moveable along the elevated platform, for example, by being slid along rails provided on the elevated platform. It may therefore be relatively easy to move the receptacle (even when full of water) such that it is in alignment with a selected channel (or channels) in the tank system. Once into position, the water receptacle may be pivotable (e.g. rotatable about a central axis) towards channels in either of the adjacent tanks in order to deliver the water surge to the selected channel of the selected tank. In this manner, a single receptacle can be used to provide water surges to a potentially large number of channels. The receptacle may have a width substantially the same as the width of a channel in order for the water surge to span the entire width of the channel. Alternatively, some underlap or overlap may be provided.

[0091] It should be noted that the water receptacle described above could be provided at locations other than the central channel of the tank system (e.g. at the distal ends of the adjacent tanks).

[0092] The tank system (or, indeed, a slab tank system having tanks that are not formed from prefabricated base portions) may also include an abalone feeding apparatus that is adapted to move along a length of each channel and broadcast food into the channel. Such a feeding apparatus may be automated (thereby saving on labour costs), may be able to access channels that would be difficult for a person to access and may be capable of more reliably and consistently distributing food for the abalone.

[0093] Any method via which the abalone feeder is able to distribute food to all abalone in the tank system can be used. In some embodiments, for example, the feeding apparatus may be slidable along rails provided on the upright walls between the channels. Such a rail network may extend all over the tank system, with the rails provided on separate base portions becoming aligned upon construction of the tank system. Thus, an automated feeder could be programmed to travel around the tank system and distribute food at appropriate times.

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[0094] The tank system (or, indeed, a slab tank system having tanks that are not formed from prefabricated base portions) may also include walkways along which a person can walk in order to access channels that either cannot be accessed or are difficult to access from the sides of the tank system. The walkways may, for example, be defined by the upright walls of the elongate base (if wide enough). Alternatively, the walkways may be separate members that are wide enough to walk on and that are adapted to be connected to the tank system in a suitable manner. In some embodiments, for example, the walkways may be adapted to be connected to one or more of the upright walls in the elongate base.

[0095] The tank system (or, indeed, a slab tank system having tanks that are not formed from prefabricated base portions) may further comprise a dual water supply in order to prevent mass mortality of abalone in the event of the primary water supply malfunctioning.

[0096] The present invention also provides a process of operating a tank system described above, for example in the manner descried below.

<u>Submersible container for holding abalone</u>

[0097] Also disclosed herein is a submersible container for holding abalone. The container comprises container walls that define an enclosure for abalone, with the enclosure comprising an internal surface for receiving abalone thereon. The container also comprises one or more apertures configured to allow water to flow through the enclosure when the container is submerged, but not to allow abalone to pass therethrough. The container also comprises one or more feeding ports in the container walls and one or more feed dispensers. Each dispenser comprises a receptacle for abalone feed and a mouth portion that is configured for receipt at a respective feeding port, wherein the one or more dispensers are independently operable to dispense feed contained therein into the enclosure.

[0098] Advantageously, the container is adapted for deployment off-shore, thereby freeing up limited on-shore resources so that the overall rate of production of abalone can be increased. Further, abalone grown in a more natural environment draw oxygen and at least some nutrients from the surrounding water, thereby negating the need for circulation pumps etc. and possibly lowering the amount of additional food required. Furthermore, the feed dispenser(s) can be used to extend the length of time between inspections of the containers, without having to resort to the complicated and expensive procedures currently employed in some off-shore abalone farms.

[0099] The submersible container may have any suitable size, shape and configuration, provided that it is capable of holding abalone in an environment where food and oxygenated seawater are readily available. The container may, for example, be elongate. The container may, for

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example, be substantially tubular shaped. Containers having such shapes may be easier to physically handle and better adapted to hold more abalone whilst still enabling seawater to flow therethrough. Other advantages of tubular-shaped containers will be described below.

[0100] In some embodiments, for example, the container may be between about 500mm and 4000mm (e.g. between about 1000mm and 3000mm or about 2200mm) in length. In some embodiments, the container may have a diameter (or cross-sectional length, in the event the container is non-cylindrical) of between about 1000mm and 500mm (e.g. between about 800mm and 400mm or about 620mm).

[0101] The container may be manufactured from any suitable material, bearing in mind that it will spend much of its life submerged in seawater and will be subject to the rigours associated with water movements as well as periodic collection, inspection and redeployment, as described below. Relatively strong plastic materials are therefore preferred (especially as these can be relatively easily formed using rotary moulding, blow moulding, etc.). The container may, for example, be manufactured from polyethylene (e.g. food grade polyethylene) using rotary moulding techniques (which are relatively cheap). The container may also, in some embodiments, be predominantly black, which provides a dark environment favoured by the abalone.

[0102] The container also includes one or more apertures that are configured to allow water to flow through the enclosure when the container is submerged. Typically, at least two apertures will be required in order to enable a cross-flow of water through the enclosure, although one large aperture might also be capable of providing this function. In embodiments where the submersible container is elongate, the one or more apertures may be provided by apertures at opposing ends of the container. In some embodiments, the container may include two (or more) primary apertures (typically larger apertures, although they may be smaller apertures arranged in a manner whereby they receive a significant flow of seawater therethrough) and a number of secondary (typically smaller) apertures.

[0103] The apertures do not to allow abalone to pass therethrough, otherwise they might be able to escape the container (or predators able to enter the container). Preventing abalone from passing through the apertures may be achieved in any suitable manner. The apertures may, for example, be provided in the form of lots of tiny holes in the container walls. Alternatively, the apertures may be provided in a mesh that covers larger apertures in the container walls (e.g. at either end thereof, in the case of an elongate container). Such mesh allows nutrients and water to feely enter and flow through the enclosure, whilst retaining the abalone. In some embodiments, the mesh may be provided in the form of rigid a sheet of material, adapted to be received within a recess in the container walls (which may help to protect the mesh from damage).

[0104] Such a mesh may be formed form any suitable material, again bearing in mind its intended use. For example, the mesh must be corrosion resistant and strong enough to withstand potentially rough seas and impacts, both whilst in the water and whilst loading/unloading from a boat. One suitable material for forming the mesh is stainless steel, for example about 1.5 mm thick stainless steel perforated with 4mm holes, with 40% of the surface area being open. A mesh that is about 1.5 mm thick has been found to be ideal because this is a thickness which the abalone are able to self-clean. In use, the abalone are able to graze on the mesh, and their mouths are physically able to access the apertures so that they can feed on algae etc. located therein. This grazing can help to prevent (or at least delay) biofouling of such meshes, hence allowing water to flow through the container for longer. If the mesh is much thicker than 1.5 mm, the abalone may not be able to physically reach its outermost side, and hence biofouling of the outermost side might occur. If the mesh is much thinner than 1.5 mm, however, its strength may be compromised.

[0105] A mesh having a pore size of about 4mm (±1-2mm) may also be beneficial because it can prevent freshly delivered food for the abalone from immediately escaping from the enclosure. Instead, the food remains within the enclosure, where it is accessible to the abalone for eating. Over time, however, the food dissolves and hence becomes smaller, whereupon it can then pass through appropriately sized pores in the mesh. In this manner, older food that has not been consumed by the abalone, will tend to be washed out of the enclosure by the flow of sea water therethrough.

[0106] Similarly, mesh having a pore size of about 4mm (±1-2mm) may also be beneficial because it can prevent baby predators that might conceivably grow into a size where they could threaten the growing abalone over the course of a year (e.g. during the first off-shore growth stage described herein) from entering the enclosure. It is possible, for example, that some predators may be in the water column (although they would typically be found on the sea floor) and might come into contact with the submersed container. In such circumstances, predators which are large enough to eat the abalone cannot pass through the mesh, but baby predators might be able to pass through, and might go unnoticed during the periodic inspections described herein. However, as the abalone are either removed from the container for grading or for market (after the first or second off-shore growth stage, respectively) after a 12 month period, and baby predator that might have been able to enter the enclosure would be discovered at such a time.

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[0107] In an embodiment where the submersible container is a cylindrical container about 2200mm long and 620mm in diameter, the submersible container may also include two 600mm diameter and 1.5 mm thick meshes formed from 316 stainless steel perforated with 4mm holes and having a 40% open area. These meshes are locatable at either ends of the container, and the container may be provided with circumferential recesses a short distance from its ends, into which the meshes can be received.

[0108] The submersible container may also have a number of apertures along its length in order to further increase a flow of water through the enclosure. Such apertures may be covered by rectangular side mesh portions being 400mm wide, 200 mm high and 1.5 mm thick, and again formed from 316 stainless steel perforated with 4mm holes and having a 40% open area.

[0109] The internal surface of the enclosure is adapted to receive abalone thereon. As abalone tend to like positioning themselves against protrusions or hiding in corners and the like, the surface is generally adapted to receive abalone thereon by including a number of protrusions on the surface. In some embodiments, for example, the internal surface may comprise a plurality of ribs on the container walls and against which abalone can reside. The ribs may, for example, be arranged substantially parallel to one another in order to make it easier to subsequently remove the abalone from the enclosure (e.g. for grading or for market). In embodiments where the container is elongate, for example, the ribs may be arranged substantially in alignment with the container's elongate axis. Such protrusions or ribs may also aid in the even distribution of food and nutrients throughout the enclosure, as these are not able to collect at the bottom of the enclosure.

[0110] Other ways to increase the available surface area within the enclosure and upon which abalone can be received (and hence how to increase the holding capacity of the container) will be described below.

[0111] Abalone contained within the submersible container may be accessed using any suitable technique. For example, if it is only necessary for a person to visually inspect the abalone to ensure that nothing untoward has happened to them, a simple visual inspection via the apertures (or feeding ports, as discussed below) might suffice. Often, however, it will be necessary to more rigorously inspect the abalone or even physically access abalone within the container. Accordingly, in some embodiments, the container may be openable to access abalone in the enclosure. The container may, for example, include one or more gates which, once opened, enable a person to access abalone within the enclosure. The container may, for example, be openable in a manner whereby the entire enclosure is readily accessible, which may help to significantly improve the ease with which abalone could be viewed and removed.

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[0112] In some embodiments, for example, the container may comprise a first portion and a second portion, the first and second portions being connected or connectable (e.g. hingedly connected or otherwise pivotable) at one side thereof and moveable between a container open and a container closed configuration. In such embodiments, a relatively simple opening action (likely in combination with an unlocking action) may be all that is required in order to open the container and fully expose the enclosure. In embodiments where the container is elongate, the portions may be connected or connectable (e.g. hinged) together at a longitudinal edges, thus further simplifying the opening action.

[0113] The first and second portions may have any shape and be adapted to interconnect via any suitable mechanism. In some embodiments, the first and second portions are substantially identical, as this will simplify construction of the portions (e.g. they may be able to be formed from the same mould). However, this need not be the case in all embodiments, and the first portion may be different to the second portion. The container may also include a third portion (etc.) connected or connectable to one or both of the first and second portions.

[0114] The first and second portions may be held in the closed configuration using any suitable locking mechanism. For example, one or both of the first and second portions may have a mechanical interlock (or a plurality of such mechanical interlocks). The mechanical interlock may, for example, be a latch that is graspable by an operator in order to release the lock. Such a latch would typically be recessed into the container wall in order for it to be difficult to open inadvertently. Such recessing would also reduce the likelihood of damage occurring to the hinges in use (most likely during collection and deployment of the container from a boat).

[0115] In some embodiments, a plurality of the submersible containers are stackable when in the container open configuration. Stacked containers will typically occupy less space and therefore be more efficient to store when not in use or when being transported.

[0116] In some embodiments, the submersible container may be adapted to be received on a surface (i.e. when out of the water) in a highly stable manner. As would be appreciated, it would not be safe to use containers which might be able to roll (or otherwise relatively easily move) when on a boat. The container may, for example be adapted to make at least three separate points of contact with the ground when in the closed configuration. The container may, for example, be adapted to make at least six points of contact with the ground when in an open configuration. Protrusions on the outer walls of the container could be used to provide this stability.

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[0117] The submersible container's walls may have any suitable construction, bearing in mind the rigours likely to be experienced by the container, as discussed above. In some embodiments, for example, the container wall may comprise inner and outer walls, with a cavity therebetween. Such a dual-walled structure imparts strength to the container, but may also provide other useful features. In some embodiments, for example, the cavity between the inner and outer walls may be adapted to receive air, water, sand (or any other suitable material), or a combination thereof, in order to adjust the buoyancy of the container.

[0118] One or more portals may be provided for pumping water (etc.) into and out of the cavity between the inner and outer walls, for example, in the form of drain plugs which can be screwed into and out of a complimentary threaded aperture in the container wall. The inner and outer walls may also be formed such that they abut one another in a number of locations, which helps to strengthen the container and may make it easier to form (e.g. by moulding).

[0119] As noted above, it would often be desirable to increase the available surface area within the enclosure and upon which abalone can be received in order to increase the abalone-holding capacity of the container. In effect, the more surface area in the enclosure, the greater the number of abalone that can be housed therein and the more efficient the farming process. Within reason of course, it is therefore generally preferable to maximise the amount of surface area inside the enclosure.

[0120] In some embodiments, the enclosure may be configured to receive a member therein, the member providing an additional internal surface for receiving abalone. The member may have any suitable form, provided that abalone can reside on it, that it can fit within the enclosure, and that it does not detrimentally impede the flow of water and food through the enclosure. As would be appreciated, the member is also ideally removable from the enclosure in order to more easily harvest any abalone thereon.

[0121] The enclosure may be capable of receiving the member in any suitable manner. For example, the enclosure may contain recesses adapted to retain a cross bar (or bars) therebetween, with the member being suspended off the cross bars. Alternatively, the enclosure may contain appropriately aligned slits or channels into which an edge of the member may be received. Ideally, the member is suspended within the interior of the enclosure, thereby leaving as much surface area as possible on the inner walls of the container for abalone.

[0122] The member itself may have any suitable form, provided it is capable of meeting the functional requirements described above. In some embodiments, for example, the member may be substantially planar, which makes the abalone easier to remove (i.e. after the member is

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removed from the enclosure) and which is easier to store when not in use. In some embodiments, for example, the member may be foldable to fit within the enclosure, and may, in some embodiments, be foldable a number of times to define a number of additional surfaces for receiving abalone. The member may, for example, be foldable such that the plurality of additional surfaces are substantially parallel to each other and separated by an abalone-receiving distance. As would be appreciated, abalone would tend to like the nooks and corners which would be formed by such folding.

[0123] In some embodiments, a plurality of the members may be present inside the enclosure (e.g. spread along the length and/or breadth of an elongate enclosure and, optionally, joined to one another in order to provide an effectively continuous surface). Fasteners may, in some embodiments, be provided to releasably attach the plurality of members together.

[0124] In a specific embodiment, the member may be provided in the form of a corrugated plastic or corriboard sheet (e.g. a planar corflute material). For example, a 1.2m x 1.2m corflute sheet (e.g. formed from polypropylene and having a thickness of about 4mm) may be folded (e.g. at fold lines which can be formed using heat techniques known in the art) to create an internal surface area for abalone to attach and feed. The sheet may include 50 mm holes for abalone to traverse the surfaces and forage for food, and 18mm holes through which can be received support rods placed into receiving lugs embedded in opposing sides of the container walls in the enclosure. Such corflute members are advantageous because they are lightweight but durable.

[0125] The submersible container also includes one or more feeding ports in the container walls, through which feed for the abalone is dispensable into the enclosure. In some embodiments, the feeding port may be defined by an aperture through the container wall, with the aperture being configured to receive a respective feed dispenser therein (e.g. using a screw thread, or the like).

[0126] The submersible container also includes one or more feed dispensers. Each feed dispenser includes a receptacle for abalone feed and a mouth portion that is configured for receipt at a respective feeding port, and is independently operable to dispense feed contained in its receptacle into the enclosure.

[0127] The delivery of feed to abalone inside the container of the present invention needs to be carefully monitored – not enough feed and the abalone will not grow at the optimal rate, but too much feed may result in water quality being adversely affected and an increase in production costs. Whilst it is possible to closely monitor the growth of abalone in on-shore facilities, to do so off-shore is much more involved. Feeding of abalone should usually take place on a weekly basis, but a significant amount of time and effort would be required to do so in an off-shore

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facility (compared to an on-shore facility). Indeed, some of the containers proposed for use with off-shore abalone farms require the use of divers or remote controlled submersible vehicles in order to feed abalone contained therein. Use of the feed dispensers described herein would significantly reduce the effort and expense associated with feeding abalone in off-shore facilities.

[0128] Each feed dispenser may be caused to dispense the feed contained therein using any suitable mechanism. The feed dispenser may, for example, be operable (or adapted) to dispense feed contained therein into the enclosure at a predetermined time or in response to a signal (generated internally or externally from the dispenser). In embodiments where a plurality of feed dispensers are used, each of the dispensers may be operable (or adapted) to dispense their feed into the enclosure at different times. Such feed dispensers may therefore be used in combination to reduce the frequency at which the containers must be retrieved from the ocean for inspection and/or feeding of the abalone, without having to resort to expensive resources such as divers.

[0129] The feed contained within the receptacle may be dispensed into the enclosure using any suitable method. In some embodiments, for example, each of the dispensers may include a gate that is moveable from a closed position into an open position upon receipt of a signal, whereby feed contained in the receptacle is dispensed when the gate moves into the open position. The gate may, for example, be spring loaded, as is described in further detail below.

[0130] In a specific embodiment, the feed dispenser for use with the submersible container of the present invention may comprise a receptacle configured to hold abalone food, a coupling configured to be received in a respective feeding port of the container, and a gate that is moveable from a closed position into an open position upon receipt of a signal. Feed contained in the receptacle is dispensed when the gate moves into the open position.

[0131] Also disclosed herein is a feed dispenser which is suitable for use with the submersible container of the present invention descried above, but which could be readily adapted for use with other abalone-containing containers or, indeed, containers containing other aquatic species. The feed dispenser comprises a receptacle configured to hold feed for abalone, a mouth portion configured to be received in the feeding port of the container, and a gate that is moveable from a closed position into an open position upon receipt of a signal. Feed contained in the receptacle is dispensed when the gate moves into the open position.

[0132] As would be appreciated, using such a feeder to automatically dispense feed to the abalone would reduce the frequency at which the abalone would need to be removed from the water to be fed. Indeed, using a number of the feeders of the present invention, it would be possible to go for significant periods of time without needing to inspect the abalone although, in

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practice, this should not exceed about a month, because the stock should be inspected at least that often to ensure that they are growing at an appropriate rate, that no predators are present, that the flow of seawater through the container is not being hindered by fouling, etc.

[0133] The signal which causes each feeder to dispense its feed into the container's enclosure may be generated internally (e.g. at the end of a predetermined time), or externally (e.g. in response to a radio or microwave signal sent from a base).

[0134] In a specific embodiment, for example, three feeders may be present on the submersible container, programmed to dispense their feed after 7, 14 and 21 days, respectively. Thus, once the abalone in the container have been inspected by an operator on a boat to ensure that they are growing appropriately, etc., sufficient food for 7 days can be added, the container closed and then returned back into the ocean. It should now not be necessary for the operator to retrieve this container for inspection etc. for 28 days.

[0135] In some embodiments, the feeders may also be adapted to provide a warning signal, for example, in the event that the feeder fails to discharge its feed or has otherwise been damaged.

[0136] The submersible container may also include additional features or components consistent with its intended use. In some embodiments, for example, the container may also include one or more attachment points (e.g. apertures adapted to receive a connecter or tether therethrough), from which the container is suspendable in the water or liftable into or out of the water in order to periodically inspect and feed the abalone, as well as to inspect and maintain the container. Typically, each container would have at least two attachment points, usually located at distal ends of the container for maximum stability when suspended in the water or when being lifted/lowered.

[0137] The submersible container may also include features or components for measuring relevant parameters, such as the flux of seawater through the enclosure, the temperature, pH, salinity of the seawater, the concentration of species such as heavy metals etc. in water inside the container. These parameters might be useful for optimising growth of the abalone, or may provide an immediate warning in the event of conditions becoming unsuitable for the abalone. The container may also include a water proof camera which is capable of transmitting visual images of the inside of the container to a remote operator. In some embodiments, it may be necessary for the container (or another component of the off-shore facility, such as a buoy attached to the longline, as described below) to include a radio transmitter in order for these images to be transmitted to the remote operator. The camera and/or radio transmitter may, if appropriate, be powered by solar energy. These instruments may be associated with the

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container in any suitable manner, for example, by inserting them into one of the feeding ports in the container (described below).

Method for growing abalone in an off-shore location

[0138] Also disclosed herein is a method for growing abalone in an off-shore location. The method comprises deploying one or more of the submersible containers of the present invention, as described above, on a long line that is anchored to the floor of the ocean, and periodically retrieving each of the one or more submersible containers and inspecting abalone contained therein (e.g. for predators, expected growth, any mortality, etc.). The method would typically also include exchanging any empty feed dispenser(s) with a full feed dispenser(s).

[0139] As will be described in further detail below, in some embodiments, the one or more submersible containers may be retrieved using a retrieval apparatus which overhangs the side of a boat. The retrieval apparatus is operable to lift the container out of the water, locate the container on a deck of the boat for inspection of abalone contained therein, and subsequently return the container to the water.

[0140] The long line may, in some embodiments, consist of a rope (back bone) between about 10 and 500 meters in length (e.g. between about 50 and 200 meters in length, or about 100 metres in length), suspended from buoys spaced therealong (e.g. at intervals of between about 1 and 100 meters, between about 5 and 50 meters or about 10m) and secured to the sea floor at its distal ends via screw anchors, concrete blocks, or the like. About 20 of the containers of the present invention may be suspended from a 100m long line (e.g. between about 1 and 3m below the surface of the water), which should result in the production of around 2 tons of abalone per annum. The off-shore facility may, for example, be about 3-hectares in size and contain about 10 long lines. Work vessels travel to and from the facility every day, the facility generally being in close proximity to the hatchery. Each 3-hectare site would be expected to produce around 20 tons of abalone per annum.

[0141] The method may, in some embodiments, comprise a first off-shore rearing stage (an intermediate growing stage), in which abalone removed from on-shore slab tanks at a size of about 25mm (after an on-shore duration of about 12 months) are placed in the containers described above and submerged in the water. Each appropriately sized container may house up to about 4,000 abalone of this size. The abalone are periodically fed and inspected, e.g. as described above, for approximately 12 months, during which time they grow to about 50 mm in size.

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[0142] At the end of the first off-shore rearing stage, the containers are removed from the water and taken by vessel to the processing facility, where the abalone are removed from the containers, graded, checked (for health and weight, with any undersize or runt animals being discarded). An appropriate number (ca. 2,000 50mm abalone) are then returned to another container for the second off-shore rearing stage (grow-out stage). The used containers are checked for any predator ingress and cleaned, ready for re-use. The abalone-containing containers are then returned using the vessel to the off-shore facility for the second off-shore rearing stage, where the abalone are grown over a further 12 months to around 80-90mm in size, at which time they are ready to be harvested for market.

[0143] Harvesting occurs at the end of the grow-out stage (i.e. after approximately a further 12 months at sea). The abalone are fed increasing amounts of food during this stage and grow by 25mm but gain 80% of their end weight. Once again, the containers are removed from the long line and taken by vessel to the processing facility, where the abalone are removed from the containers and graded for size. They are then processed for one of the many different styles of market product, including live, frozen, canned, IQF (individually quick frozen) or dried. The containers are then cleaned for re-use in the first or second off-shore rearing stage.

[0144] As noted above, abalone inside the containers are periodically inspected during the intermediate and grow-out stages to ensure that they are growing at the expected rate and that nothing untoward has happened to them. The containers must all be removed from the water, typically about every month in order to replenish the feed dispensers, during which time a visual inspection of abalone in each container may be made (either through the feeding ports or by opening the container). In the interim, however, it is good practice to monitor the abalone on an ongoing basis, and this may be achieved by performing regular inspections of abalone in random containers (e.g. a random container on each longline each few days or each week). During such an inspection, a single container on a long line can be retrieved and its contents inspected (e.g. via the apertures, by removing a feed dispensers and looking into the container via the feeding port, or by opening the container). If the abalone in the inspected container are growing as expected, then it can be reasonably inferred that the abalone in the surrounding containers are too. Thus, a regular inspection process can be performed, but with a fraction of the effort required to perform a full inspection.

[0145] The containers may advantageously be deployed from and retrieved by a maintenance boat or vessel without the need for divers. Further advantageously, the long line allows the containers to drift with tidal ebbs and flows, thereby minimising any effects of shadows cast in the seabed and improving the “environmentally friendly” nature of the facility. Furthermore, as

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the containers are suspended beneath the sea surface, water flow therethrough can be maximised, thus providing greater nutrition and oxygenation as compared to farms that are located in a fixed position.

[0146] In some embodiments, the one or more submersible containers may be retrieved using a retrieval apparatus that overhangs the side of the boat or vessel, the retrieval apparatus operable to lift the container out of the water, locate the container on a deck of the boat for inspection of abalone contained therein, and subsequently return the container to the water.

[0147] The retrieval apparatus may also be able to engage and raise the longline out of the water and to a convenient height such that the containers attached thereto may be accessed be persons on the boat, preferably without having to be removed from the long-line. The retrieval apparatus may also be operable to position the container on the deck of the boat, where the abalone can be inspected in a highly convenient manner (e.g. by opening in the container whilst it is sitting on the deck and not suspended from the side of the boat).

[0148] The retrieval apparatus may have any structure that is suitable for achieving the functions discussed above. A specific form of the retrieval apparatus is described, by way of example only, below.

[0149] Specific embodiments of the present invention will now be described, by way of non-limiting example only, with reference to the accompanying drawings.

[0150] Referring firstly to Fig. 1, there is shown a tank system 10 in accordance with an embodiment of the present invention. Tank system 10 has eight prefabricated base portions 12, arranged in an array that is two base portions wide and four base portions long. A central trough 14 divides the array of base portions in half. Each base portion 12 is about 5 m wide and about 9 m long such that, when combined as shown, eight channels, shown generally as 16, are provided, each of which has a width of about 2.5 m and a length of about 18 m. The floor of each base portion 12 is about 150 mm thick, which provides an appropriate balance of strength versus weight.

[0151] Each base portion 12 has three upright walls, shown generally as walls 18, which extend for the length of the base portion 12 and align with corresponding walls on the adjacent base portion to thereby define the channels 16 therebetween. Walls 18 are about 150 mm high, which easily enables a water depth of about 70mm (see Figure 2) to be maintained in the channels 16 for the abalone to move about, feed and grow. In some embodiments (not shown), an upper portion of the walls 18 may be provided with rails, along which an automated feeder may travel. The structure of walls 18 will be described in further detail below.

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[0152] Each prefabricated base portion 12 is precast from concrete and will weigh about 10 tonnes so that it can be transported and assembled using conventional equipment. Although not shown, the surfaces of the base portions 12 on which abalone will reside may include ridges or the like, which provide refuges for the abalone. The ridges are preferably created during the manufacture process, and can either be arranged in a transverse orientation in the channels, or in other orientations such as a longitudinal orientation so as to, for example, assist the flow of water along the channels 16. An upper portion of the walls 18 may also include a coating (not shown) to help prevent the abalone from escaping.

[0153] In an alternative embodiment (see Figure 6), the base portions 112 could be provided with a width of about 10 m and length of 9m, meaning that a 8-channel tank system 110 similar to tank system 10 would only require four base portions 112. Whilst it may be advantageous to use fewer base portions to manufacture the tank system, however, such advantages must be carefully assessed in light of the difficulties involved with transporting and installing larger (and hence likely heavier) components.

[0154] As will be apparent to a person skilled in the art, the tank system 10 (and 110) can provide not only efficiencies in construction when compared to existing slab tank construction methods (i.e. concrete pours), but also in the operation and ongoing maintenance of the tank system 10 in abalone aquaculture (as will be described below). The tank system 10 provides an environment for nurturing juvenile abalone from plate tanks to a size of about 25mm, after which they may be collected and, for example, placed in an off-shore facility for further growth. Alternatively, the juvenile abalone can be grown to a marketable size in the tank system 10 if no off-shore facility is available.

[0155] Although not shown, prefabricated base portions 12 (and 112) may include other components of the tank system 10 (and 110) such as, for example, plumbing components, electrical components or components that facilitate the attachment of other parts of the tank system to the base portions. Such components can be pre-cast within the prefabricated base portions during their manufacture.

[0156] Prefabricated base portions 12, 12 are joined end-to-end at join 20, which is also shown in Figure 1 in magnified form. Join 20 has an overhang-underhang arrangement, where a protrusion 22 on one edge of base portion 12 is received on a lip 24 on the edge of the adjacent base portion 12. The degree of overlap of join 20 is typically about 50 mm, and the pressure on the join 20 is usually sufficient to render it watertight (although in some circumstances the join 20 may also be provided with a seal, not shown). A join such as join 20 may not necessarily be required to join laterally adjacent prefabricated base portions 12, 12, as a watertight join between

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these portions should not be necessary because of walls 18, 18. The adjacent base portions 12, 12 may be connected using any suitable means, such as clamps or other fasteners (not shown), or may remain in their respective locations due to their weight.

[0157] The distal ends of each base portion 12 do not have walls, but are open ended and thereby able to engage end troughs 26, 26 and the central trough 14 in the manner described below. As will also be described in further detail below, the end troughs 26, 26 and central trough 14 provide both a supply of water to channels 16 and a drain for that water. In use, the water may be arranged to flow through the channels 16 in one direction for a predetermined period of time, and then in an opposite direction for another predetermined period of time. Such a flow of water mimics tides, and helps to evenly feed and oxygenate the abalone, as well as to clean the channels 16.

[0158] Referring now to Figs. 2 and 3, an end trough 26 and the surrounding parts of portions 12, 12 are shown in greater detail. End trough 26 is adapted to supply water to, and drain water from, the tank system 10. The end trough 26 is adapted to sealingly engage the edge of the prefabricated base portions 12, 12, such that it is in fluid communication with all four of the channels 16. Trough 26 has a first longitudinal wall 28 and a second longitudinal wall 30. The first wall 28 is adapted for engaging the underside edges of the bases 12, 12 (i.e. as shown in Figure 2), and is lower than the second wall 30 (i.e. when the end trough is in its working configuration). These height differences enable the trough 26 to be in fluid communication with and retain water in the channels 16, without water being able to spill over wall 30 (as can be seen in Figure 2). End trough 26 also includes partitions 32 (see Figure 3), which align with the walls 18 in order to appropriately position the prefabricated base portions 12, 12 with respect to the end trough 26 (as will be described in further detail below) and substantially prevent flow of water from one channel 16 to another channel 16 (which might cause cross-contamination of the channels 16, 16). End trough 26 also includes raised end portions 34, 34 at its distal edges, which align with the walls 18, 18 at corresponding edges of the base portions 12, 12 in order to prevent water from escaping the system 10.

[0159] As can be seen in Figure 3, the central partition 32 of trough 26 extends over and above wall 28 and has a width that can be received within a gap between walls 18, 18 of the adjacent base portions 12, 12. As noted above, this arrangement can help to ensure an appropriate (watertight) alignment of the base portions 12, 12 and the end trough 26, as well as with each other. The base portions 12, 12 and the end trough 26 are appropriately aligned with each other when the central partition 32 of trough 26 is received within the gap between walls 18, 18, and

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the other walls 18, 18 of each base portion 12, 12 abut and are in alignment with the partitions 32, 32 and raised ends 34, 34, respectively.

[0160] The central partition 32 of trough 26 and gap between walls 18, 18 of the adjacent base portions can also provide another advantage. As would be appreciated, it would be a relatively simple matter for an operator to visually inspect the four outermost channels 16 of tank system 10. However, the innermost four channels 16 are not as easy to inspect, due to them being over 2.5m from the edge of the system 10. It may therefore be useful to provide a walkway (not shown) along the centre of the tank system 10, so that an operator can walk between the innermost four channels 16. In this respect, as the walls 18 and partitions 32, 34 are all about 150 mm wide, the total width of the central wall (i.e. including walls 18, 18 of the left and right base portions 12, 12 and with the partition 32 therebetween) would be about 450mm wide – i.e. wide enough to walk on. Alternatively, a walkway (not shown) could be provided above the central portion of the system 10, with a rib on its underside adapted to be received between walls 18, 18 of the left and right base portions 12, 12 and thereby support the walkway.

[0161] One or more pipes 36 (see Figure 2) is provided to deliver a flow of seawater into the end trough 26. If only one pipe is present, then the partitions 32 must not extend all the way to the floor of the trough 26 in order for water to flow underneath the partitions 32 and subsequently into each channel 16. Alternatively, a pipe 36 may be provided for each channel 16 (although this would involve more infrastructure). When water is flowing into the channels 16, 16, 16, 16 from end troughs 26, 26, the volume of seawater flowing out from the pipe or pipes 36 is controlled to provide the appropriate flow rate through the channels (and to maintain an appropriate level of water in the channels).

[0162] End trough 26 also includes a drain (or drains) 37, which are openable to drain a selectable volume of seawater from the trough. When water flow is reversed and the water is flowing from the channels 16, 16, 16, 16 into the end troughs 26, 26, the volume of seawater draining through the drains 37, 37 is controlled to provide the appropriate flow rate through the channels (and to maintain an appropriate level of water in the channels).

[0163] The walls 28, 30 and base of end trough 26 may have a thickness of about 150 mm and, similar to the prefabricated base portions 12, may be precast concrete. The system 10 may also include barriers or grates (not shown) to prevent the abalone from travelling into the end trough 26 (and the central trough 14).

[0164] Referring now to Figs. 4 and 5, central trough 14 is shown in greater detail. As with end troughs 26, 26, central trough 14 spans the entire width of the array of adjacent bases 12, 12 and

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is adapted to supply water to, and drain water from, the tank system 10. Each edge wall 38, 38 of the central trough 14 can receive and sealingly engage the undersides of edges of the aligned prefabricated base portions 12, 12, such that the central trough 14 is in fluid communication with all of the channels 16 in the system 10.

[0165] Similar to end trough 26, central trough 14 also has partitions, shown generally at 39 and 40, which align with and abut or receive the walls 18 therein and substantially prevent flow of water from one channel 16 to another channel 16, as described above. As can be seen in Fig. 4, the central partition 40 is adapted to be received in the recess located between walls 18, 18 of the adjacent bases 12, 12 so as to ensure appropriate alignment of the base portions 12, 12 at both ends (i.e. in conjunction with central partitions 32, 32 of end troughs 26, 26). Once so aligned, a substantially water-tight seal is formed between the central trough 14 and the channels 16.

[0166] In Fig. 5, the central trough 14 is shown having water supply means in the form of water inlets 41, 41 and water draining means in the form of drain 42. The water inlets 41 and drain 42 are selectively operable (in combination with the equivalent features in the end troughs 26, 26) in order to achieve the desired direction of flow of water through the channels 16.

[0167] Also shown (in part) in Fig. 5 is a wave generator 44, which includes a rotating barrel 46 that is operable to generate a wave of water that can help to clean the channels 16 by removing any debris and waste material that may have collected therein. Periodic flushing of the channels 16 will help to maintain the abalone in good health and may help to improve muscle mass. The wave generator 44 is located on a ledge 48 positioned above the central trough 14 such that waves can be caused to flow in either a left or right direction (looking at Figure 5) and hence flush out channels 16 on either side of the central trough 14. Alternatively (and as is shown in Figure 6, for example), the wave generator 44 may instead (or additionally) be located above one or both of end troughs 26, 26, where waves would to run through the channel 16 and into the central trough 14.

[0168] The wave generator 44 includes means for filling the rotating barrel 46 with seawater, such as a tap, hose, or the like (not shown). The rotating barrel 46 is rotatable and includes a large aperture for rapidly releasing the water therefrom (not shown). In this manner, an operator may fill the barrel 46 and then quickly rotate the barrel 46 to release the water into a desired channel 16. This operation could also be performed automatically, if appropriate infrastructure were provided. The barrel 46 may be rotated in either direction so as to be able to create a wave in either direction. In another embodiment, the barrel 46 may be provided in an unstable configuration, such that filling the barrel 46 (e.g. via a continuous supply of water) causes the

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barrel 46 to tip from time to time (once a certain volume of water is contained therein), thus creating the periodic waves.

[0169] The wave generator 44 may also include wheels 50, which may be set upon rails 51 provided on ledge 48, so as to be slidable between adjacent channels 16. In this manner, an operator may use the barrel 46 to flush a first channel 16, and then push the barrel 46 along the rails 50 until it is positioned above a second channel 16 and the process repeated.

[0170] In an alternative embodiment (not shown), the wave generator may include at least one spray for spraying water. In this alternative embodiment, the wave generator relies on moveable jets of spray to create a wave. Specifically, the wave generator comprises spray jets mounted on a gantry or the like, wherein the gantry is moveable up and down the length of the channel (or channels) 16. In use, an operator would position the gantry at one end of the channel 16, activate the sprays, and then move the gantry along the length of the channel 16. The sprays may be orientated in the direction of movement, such that a wave is generated. Furthermore, the direction of the sprays may be user configurable, such that the operator may orientate the sprays in an opposite orientation for the return trip along the channel 16. In this embodiment too, the gantry may be located on rails (not shown), such as rails located atop the walls 18.

[0171] An alternative embodiment of the tank system is shown in Figure 6 in the form of tank system 110. Tank system 110 has four prefabricated base portions 112, arranged in an array that is one base portion 112 wide and four base portions 112 long. A central trough 114 divides the array of base portions in half. Each base portion 112 is about 10 m wide and about 9 m long such that, when combined as shown, four channels, shown generally as 116, are provided having a width of about 2.5 m in each half (i.e. system 100 has eight channels 116 in total). Tank system 110 also includes three wave generation means 144, positioned above the central 114 and end 126, 126 troughs.

[0172] The prefabricated base portions 112 of tank system 110 are not placed directly on the ground but in a raised position. Such an arrangement is advantageous in that space for the central 114 and end 126, 126 troughs is provided, and there is no need to prepare foundations. In one embodiment, a prepared level is provided using piers, such as screw piers which are shown generally at 160. In this manner, during construction, the screw piers 160 are screwed into the ground to the prepared level, whereafter the prefabricated base portions 112 are (either separately or together) placed atop the screw piers 160. Screw piers 160 also provide support for the central 114 and end 126, 126 troughs, with the prefabricated base portions 112 positioned with respect to the troughs in the manner described above. The relative height of each screw pier

160 may be adjusted by screwing the pier 160 into or out of the ground in order to provide a substantially even support for the entirety of the tank system 110.

[0173] Referring now to Fig. 7, there is shown a water supply and drainage system 200 for supplying a flow of water to the eight channels, shown generally as 216, in the tank system 210. The supply system 200 has a primary supply line 270. The primary supply line 270 usually draws water directly from the ocean. The supply system 200 also includes a secondary, backup, line 280 for occasions where the primary supply line 270, for whatever reason, fails or provides an inadequate flow of water. The primary supply line 270 and the secondary backup line 280 are able to supply water to both the end water supply and drain troughs 226, 226 and the central water supply and drain trough 214.

[0174] The drainage system 200 comprises drain outlets, shown generally at 290, selectively operable by control valves, shown generally at 292. The drain outlets 290 feed into drainage spurs 294, which may include one or more man holes for access (not shown). The drainage spurs 294 feed into one or more settling ponds (also not shown), where the water can be stored before returning to the ocean (treated if necessary).

[0175] Referring now to Fig. 8, an exemplary array of tank systems 10 (or 110 or 210) is shown. The tank array comprises six tank systems, shown generally as 10, which may be housed in a shed 60. The shed 60 may, for example, provide a darkened environment favoured by abalone. The shed 60 comprises a work and storage area 62, accessible by one or more doors 64. A water supply and drainage system similar to that described above with reference to Figure 7 may be used to supply water to all of the tank systems 10 inside the shed 60.

[0176] Referring now to Figures 9 to 12, a submersible container for holding abalone is shown in the form of tube 300 in Figure 9 and tube 301 in Figures 10 to 12. Tubes 300 and 301 are identical except in respect of the number of feeding ports they have, with tube 300 having three feeding ports and tube 301 having only one feeding port. Common features of tubes 300 and 301 will be described below using the same reference numbers.

[0177] In this embodiment, tubes 300 and 301 are tubular in shape, with an internal diameter of about 570mm and a length of about 2200mm. The shape of tube 300/301 may, however, be configured according to its intended application and may be spherical or the like, or may be non-circular in cross section (e.g. oval, triangular, square, etc.). A tubular shape advantageously provides ease of handling whilst allowing for the passage of water through the tube 300/301, with the tube usually being aligned with tidal flows and/or ocean currents in use to maximise water flow therethrough. The tube 300/301 may be manufactured from a suitable plastic

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material, such as polyethylene, and preferably food grade polyethylene so as not to risk contaminating the abalone for human consumption. Tube 300/301 is preferably black (at least inside), because abalone prefer dark environments. Highly visible colouring on the outside of tube 300/301 may, however, make it more visually distinct and hence easier to locate whilst in the water.

[0178] The tube 300/301 includes two halves, an upper half 302 and a lower half 304. Upper 302 and lower 304 halves are joined along one edge by hinges, shown generally as hinge 306. The hinge 306 may be an integral hinge with a PVC or PE hinge rod. As can be seen by comparing Figures 9 and 10, tube 300/301 is completely openable in order to access its inside for cleaning, maintenance and harvesting of abalone. Upper 302 and lower 304 halves are substantially the same as each other, enabling the tube 300/301 to be manufactured from the same plastic injection or rotation mould (the tube comprises no overhangs, allowing it to be manufactured from single plastic injection or rotation mould). As can also be seen in Figure 10, empty tubes 300/301 can be stacked together when in an open configuration for ease of storage.

[0179] The tube 300/301 also includes a releasable mechanical interlock, shown generally in the form of latch 308 (see Figure 10), which allows tube 300/301 to be locked in its closed configuration. Each latch 308 includes a male prong 310 on an edge of the lower half 304, which is adapted to be received within a corresponding recess 312 on an edge of the upper half 302 (or vice versa). A tongue on prong 310 is retained by a corresponding groove in recess 312 such that, once in its closed configuration, a simultaneous pushing and opening action (highly unlikely to be performed inadvertently, especially when there are a number of latches 308 to be opened) is required to open the tube 300/301. As can also be seen in Figure 10, the latch 308 is recessed, so as to avoid damage in use and to reduce the likelihood of it being opened inadvertently, wither in the ocean or whilst being loaded/unloaded.

[0180] The walls of tube 300/301 are of a dual layer construction, having an outer layer (clearly visible in Figure 9) and an inner layer (clearly visible in Figure 10), which define a cavity therebetween. This cavity may be filled with water, air, sand or a combination thereof in order to adjust the buoyancy of the tube 300/301, with apertures having plugs 314 being provided in the upper 302 and lower 304 halves to facilitate this. The inner and outer layers also both include a number of dimples, shown generally at 315, which abut each other inside the cavity in order to increase the structural rigidity of the walls. The dimples 315 may be generally cone shaped, which can help to further increase the strength.

[0181] The tube 300/301 also has two lifting lugs, shown generally at 316, at each end of each half 302, 304. Lifting lugs 316 are integrally formed with the tube walls and include an aperture into which a rope or other means of attachment can be received in order to suspend the tube 300/301 in the water and/or to retrieve and deploy the tube (as described below). As can be seen in Figures 9 and 10, the lifting lugs 316, 316 are also configured such that each half of the tube 300 makes at least two (and preferably three, as is shown in the Figures) points of contact with the ground in order to prevent the circularly-shaped tube 300/301 from being able to roll when resting on a surface (e.g. the deck of a boat).

[0182] Whilst the tube 300/301 may be located on the sea floor whilst the abalone contained therein grow, it is generally preferable that it be suspended in the water column (i.e. where it is easier to access for inspection, more likely to be exposed to tidal flows and ocean currents, less susceptible to predators and biofouling, etc.). The upper half 302 of tube 300/301 therefore also has an aperture, shown generally at 318, at each end for receiving a tether (not shown) via which the tube may be suspended in the ocean, e.g. from a long line (described below). The tether may be fed through the aperture 318, and tied, using a secure knot such as a sailor's knot, to secure the tube 300/301 to the tether. In this manner, the tether is able to travel freely through the aperture, allowing the tube 300/301 to drift up and down in the ocean current. Apertures 318 are upwardly orientated in use so as to engage the tethers. Corresponding apertures, shown generally at 319, may also be provided on the lower half 304 to which weights may be attached, for example.

[0183] As can be seen in Figure 10, the internal surfaces of the upper 302 and lower 304 halves include a number of longitudinally extending ribs, shown generally at 320. Ribs 320 promote abalone habitation by allowing for the collection of food and providing obstacles against which abalone can rest. Ribs 320 may also help to increase the structural rigidity of the tube 300/301.

[0184] Tube 300/301 also includes a number of apertures configured to allow water to flow through its interior. Tube 300/301 includes end apertures 322 and 324, as well as a number of side apertures, shown generally at 326. As apertures 322, 324 and 326 are quite large, in order to prevent abalone from escaping, they are covered by a mesh, shown generally as mesh 328 (mesh 328 covers end aperture 322 in Figure 9). Mesh 328 allows water to flow therethrough in use, but is too fine for abalone to pass through. Mesh 328 is formed from corrosion resistant stainless steel, and has a thickness and pore size that enable abalone to self-clean it by grazing (in the manner described above). Mesh 328 is provided in the form of a circular disk with a rubber ring (not numbered) around its periphery. The rubber ring is adapted for receipt in recesses 330, 330 that are located at opposing ends of the upper 302 and lower 304 halves (see Figures 10 and 12). Each recess 330 is located a short distance inside the interior of the tube 300/301, so as to protect the mesh 328 from impact and damage. Once tube 300/301 is closed, the mesh 328 is securely retained within the recess 330 at each end thereof, with the enclosure for abalone being defined therebetween.

[0185] The upper half 302 of tube 300 also includes three feeding ports shown at 332, 332 and 332, each of which is adapted to receive a feed dispenser (which will be described below) therein. Feeding ports 332, 332 and 332 are evenly spaced along the length of tube 300. Similarly, the upper half 302 of tube 301 includes one, centrally located, feeding port shown at 332. Each feeding port 332 has a screw thread (not shown) into which a feed dispenser may be screwed and extend through into the interior of the tube, as will be described in further detail below. When they do not hold a feed dispenser, the feeding ports 332 may be covered with a removable stopper, such as a bung or screw-type stopper (not shown).

[0186] Referring now to Figures 11 and 12, the tube 300/301 is shown containing a member for increasing the available surface area for abalone inside the tube, in the form of a folded corflute sheet 334. As described above, increasing the available surface area inside the tube 300/301 will increase the abalone-carrying capacity of the tube. The sheet 334 is folded into a concertina-type configuration and is located and held in position within the tube 300/301 by at least one (typically three, for a tube of this length) internally located cross bar 336. As can be seen, sheet 334 is suspended within the tube 300/301, and therefore does not detrimentally affect the abalone-carrying capacity of the tube's inner walls. Cross bar 336 engages the interior of the tube in the manner described below. Depending on the size of the sheet 334 and length of the tube 300/301, more than one sheet 334 may be provided so as to maximise the available surface area inside the tube.

[0187] In this manner, a maximum surface area is provided within the tube 300/301 so that the greatest number possible of abalone can be held therein. Further, the concertina-type shape of the member provides a number of nooks and crannies in which the abalone may hide and where food may gather, providing an ideal growing environment for the abalone. Advantageously, however, as sheet 334 is provided in the form of a single member that is substantially planar when unfolded, it is easy to remove from the tube (i.e. in one piece) and, once unfolded, very easy to remove abalone therefrom (there are no corners etc. for the abalone to hide). The orientation of sheet 334, substantially parallel to the longitudinal axis of the tube 300/301, enables a sufficient volume of oxygenated seawater to flow through the tube.

[0188] Figure 13 shows an alternative embodiment of the sheet 334 in an unfolded configuration and in the form of sheet 337. Sheet 337 has a similar construction and form (when folded) to that of sheet 334 and is otherwise identical to sheet 334 except for a slightly different configuration of apertures thereon (described below). Sheet 337 has a number of pre-fold lines

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shown generally as 338, such that it is readily able to be folded into the configuration shown in Figures 11 and 12. Pre-fold lines 338 may be applied to the sheet 337 (and to sheet 334) during construction, or may be added on-site, using any suitable heat- or ultrasound-based techniques. The sheet 337 (and 334) includes relatively thinner connective strips, shown generally as 340, between relatively wider panel portions, shown generally as 342. Connective strips 340 have a width that is sufficient to provide a distance between adjacent panel portions 342, 342 (i.e. when folded) whereby abalone are free move around unhindered.

[0189] The sheet 337 also has an array of relatively large apertures, shown generally as 344, which allow the passage of abalone, food, oxygenated water, etc. therethrough. In the embodiment shown, the large apertures 344 are arranged such that each panel portion 342 includes two apertures 344, and each connective strip 340 includes three apertures 344. The smaller apertures shown generally as 346 are sized and located to receive the cross bars 336 therethrough when sheet 337 (or 334) is in a folded configuration so that the folded sheet can be mounted within the interior of tube 300/301, as described above (see Figure 12).

[0190] The sheet 337 also has one or more fasteners 348 (only one fastener is shown in Figure 13 for clarity) for fastening adjacent panel portions 342, 342 to each other and thus holding the sheet 337 (or 334) in the concertina-type arrangement shown in Figures 11 and 12, regardless of other forces which may press on the folded sheet in use. The panel fasteners 348 include a releasable mechanical interlock such that the panel portions 342, 342 are releasably fastened together via a slot and tab arrangement. In this regard, panel fasteners 348 have tabs 350 which can be inwardly folded so that the fastener 348 can be inserted into a respective slot, shown generally as slot 352, of an adjacent panel 342. Once through the slot 352, the tabs 350 would tend to resiliently unfold, thereby making the fastener 348 too large to pass back through the slot 352. Preferably, the panel fasteners 348 are press-cut so as to be integral with the portion 342, with the fasteners 348 being foldable out in use for insertion into slot 352. Alternatively, the panel fastener 348 may be adhered to the surface of the adjacent panel portion 342, although this arrangement may result in damage to the panels and/or fastener when the sheet 334 is removed from the tube 300/301 and unfolded in order to more easily access the abalone thereon.

[0191] As best shown in Figure 11, the sheet 334/337 is foldable to define an outer profile having a shape adapted to fit within the circularly-shaped inside of the tube 300/301 in use. As such, the width of panels 342 can vary, becoming progressively narrower towards the edges of the sheet 334/337.

[0192] As noted above, sheets 334 and 337 are manufactured from a corflute material, which is lightweight and durable. The preferred direction of the flutes are shown by cut-out 354 (see

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Figure 13). Such a direction advantageously allows for elongate rigidity of the sheet 334/337 and allows any entrapped air to escape when submerged. The corflute material may be manufactured from food-grade material, and may be black as the abalone prefer dark environments.

[0193] At the end of the abalone growing period, the folded sheet 334/337 may be removed from the inside of the tube 300/301 (i.e. once removed from the water and opened), and unfolded so that a substantially planar surface is provided. As would be appreciated, it is far easier to remove abalone from a planar surface than from a folded surface.

[0194] As will be described in further detail below, the tube 300/301 is adapted for use in an off-shore abalone farm in a submerged configuration. Three thousand or more juvenile abalone about 25 mm in length may be introduced into the tube, being regularly fed (about every 1-2 weeks, for example as described below) with suitable manufactured food. After about 1 year, the abalone will have grown to about 50mm in length and are then ready to be removed from the tube, graded for size, and approximately 1800 abalone about 50mm in length loaded back into tube (not necessarily the same tube). The freshly-loaded tube will then again be submerged in an offshore farm for approximately another 12 months. After this time, the tube is opened and the mature abalone being approximately 90mm in diameter are removed and made ready for market.

[0195] Referring now to Figures 14 to 18, a feed dispenser for use with the tube 300/301 (for example) is shown in the form of dispenser 400. Dispenser 400 has a screw thread 402 for coupling with the feeding port 332 of tubes 300 and 301 (in the manner described below) and a lid 404. As can be seen by comparing Figures 14 and 15, the lid 404 is operable to move between a closed position (Figure 14) and an open position (Figure 15). Once lid 404 is open, the interior 406 of the dispenser 400 is accessible, as will be described in further detail below. Lid 404 is joined to the dispenser 400 along a hinge 408 and is generally biased towards the open position such that it rapidly opens and moves to the position shown in Figure 15 upon release. Lid 404 has a number of tabs, shown generally as 410, which are configured to be received in complementary recesses, shown generally as 412, in the dispenser 400. The lip that can be seen on tab 410 interacts with a complimentary protrusion (not shown) within recess 412 such that the lid 404 remains closed until such time as the protrusion is moved, whereupon the lid 404 springs open.

[0196] The length of time for which the lid 404 stays closed may be predetermined, e.g. by a user immediately before they couple the charged dispenser 400 with the feeding port 332 of tube 300/301. Alternatively, the length of time for which the lid 404 stays closed may be controlled externally. In the embodiment shown, for example, dispenser 400 includes a timer (not shown)

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and a rotatable sheath 414, which can be rotated with respect to the remainder of the body of the dispenser in order to adjust the length of time until the lid 404 will open. Indicia, shown generally as 416, may be included in order for the operator to accurately set the desired time period. The indicia may, for example, indicate the number of hours, days or weeks until the timer will cause the lid 404 to open. Typically, the indicia will indicate time periods of 1, 2, 3 or 4 weeks, but even up to 5 weeks.

[0197] Referring now to Figure 16, the opposite end of dispenser 400 is shown, which includes a recessed portion (not numbered) and a handle 418 to make the dispenser easy to carry. The dispenser 400 also includes a valve 420, via which air can be pumped into the interior 406, for the reasons described below.

[0198] Referring now to Figure 17, a cross sectional view of the dispenser 400 is shown in order for its interior 406 and its workings to be more clearly seen. An internal chamber 422 configured for holding and then rapidly dispensing feed for abalone is defined inside the dispenser 400. The internal chamber 422 may, in some embodiments, include a plunger 424, which is operable to rapidly move in a downwards direction (referring to Figure 17) upon opening of the lid 404 such that the food contained therein is rapidly ejected from the chamber 422. As the food will be deployed in an underwater environment and water will rapidly flow into the chamber 422 once the lid 404 opens, it is generally preferable that the food be ejected quickly, lest the inflow of water cause not all of the food to be dispensed. The plunger 424 may be operated via any suitable mechanism (not shown), such as via a spring mechanism or via compressed air (e.g. pumped in via valve 420). In some embodiments, plunger 424 may not be required, for example, the internal chamber 422 could be pressurised with air such that, when the lid 404 opens, the air and its entrained abalone feed is very rapidly ejected out from the chamber 422.

[0199] Referring now to Figure 18, the dispenser 400 is shown (in a lid open configuration) screwed into a feeding port 332 of the upper half 302 of a tube 300 (as described above, tube 301 could instead be shown). As can be seen, the thickness of the threaded portion 402 of the dispenser 400 is about the same as the thickness of the walls of the tube 300 such that a substantially flush surface is provided therebetween (which can help to reduce biofouling). Further, in its open configuration, lid 404 is positioned whereby it cannot hinder the removal of the spent dispenser 400 from the tube 300 (e.g. during inspection and recharging). All that an operator needs to do is to unscrew the dispenser 400 from the tube 300 and move it directly away from the tube 300.

[0200] As abalone will tend to move all over the interior of the tube 300, it will generally be necessary to protect the opening of the dispenser 400 from abalone being situated on or over it, which might cause its lid 404 to not open. One method via which this may be achieved is to use a shield 426, typically made from a mesh material which will allow water and feed, but not abalone, to pass thorough. The shield 426 may, for example, be made of the same kind of stainless steel mesh described above, which the abalone could crawl over and clean in a similar manner. As can be seen, the edges of the shield 426 which abut the inner wall of the tube 300 should be substantially coplanar with that surface, otherwise biofouling may occur at the raised edges. The edges of the shield 426 may, for example, be recessed slightly into the inner wall of the tube 300, although this may not be necessary if the material from which the shield 426 is made is sufficiently thin.

[0201] In use, an operator will select an appropriate dispenser 400 which is full of feed for the abalone and which has its lid closed. The dispenser may, for example, be colour coded to indicate either a type or quantity of feed contained therein (e.g. suitable for abalone of a particular size) or to indicate a time delay before the lid 404 will open. In embodiments where the tube 300 has three feeding ports 332, the operator will choose three appropriate dispensers 400 and screw them into their respective ports. In alternative embodiments (not shown), the dispenser may be adapted to be securely received in a feeding port via a snap-fit, bayonet-fit, frictional fit, etc.

[0202] Each of the dispensers 400 will be configured to open its lid and hence dispense the feed contained therein into the tube 300 at predetermined intervals, as described above. For example, a red dispenser may be configured to open its lid after 1 week, an orange dispenser after 2 weeks and a green dispenser after 3 weeks. One week after the lid of the green dispenser has opened, the tube 300 will be scheduled for removal from the water, its abalone checked and the three spent dispensers 400 replaced with fresh dispensers 400.

[0203] In alternative embodiments (not shown), the dispenser 400 may include a signal receiver which, upon receipt of an appropriate signal, causes the lid 404 to open. In this manner, signals generated by an external source (e.g. by a computer system that manages the abalone farm) can be used to control the rate at which abalone within the tube 300/310 are feed. The dispenser 400 may also include a transmitter (again, not shown), which transmits a signal if a predetermined event (e.g. non-opening of the lid 404) occurs. Receipt of such a signal would trigger an appropriate alert, for example, that the tube 300/301 be retrieved out of schedule in order to feed the abalone and replace the malfunctioning dispenser.

[0204] Referring now to Figures 19 and 20, a portion of an off-shore farm for rearing abalone is shown. As best shown in Figure 19, a long line 500 is anchored to the sea floor at either end using concrete blocks 502 (or other suitable means). A number of floats, shown generally as floats 504, are positioned along a length of the longline 500 and maintain the longline 500 at a desired distance just under the surface of the water. A number of tubes 300 (tubes 301 could instead, or additionally, be used) are tethered to the longline 500 and are suspended underneath the surface of the water. The longline 500 may have any length and, in the embodiment shown, is around 100 m long. Six floats 504 are spaced roughly evenly along the longline 500, with four tubes 300 being suspended between adjacent floats 504 (i.e. the longline 500 holds twenty tubes 300 in total).

[0205] The rise from the anchor 502 to the first float 504 may be about 10 meters in length, but may be adapted to lengthen and shorten to account for tides and depth of water. However, even if the riser portion is static and the farm includes other longlines nearby (typically such longlines would be arranged parallel to one another and approximately 30m apart), each longline and its dependant tubes would tend to drift in the same direction as the flow of the tide, thereby preventing interference therebetween.

[0206] Referring now to Figure 20, the tubes 300 are shown hanging from the longline 500 via tethers 506, 506, which are attached to the apertures 318, 318 at distal ends of the upper half 302 of tubes 300. Tethers 506, 506 have a length such that the tubes 300 are suspended about 1m below the surface of the water, which has been found to be an ideal abalone-growing depth. As will be described in further detail below, the tubes 300 hanging from the long line 500 are able to be lifted to a boat from time to time for maintenance, feeding and inspection of the abalone, etc., without usually having to utilise divers.

[0207] Referring now to Figures 21 and 22, shown is a boat 600 having two retrieval apparatus 602, 602 on one side thereof. The boat 600 includes a substantially flat working area 604, on which tubes 300 (or 301) can be placed and opened in order to visually inspect and feed the abalone contained therein. In some embodiments (not shown), the substantially flat working area may be provided in the form of a deck which can slide out from the side of the boat 600, which may help to make the tubes 300 suspended adjacent to the boat even easier to access.

[0208] The retrieval apparatus 602, 602 are adapted to lift the longline 500, and any tubes 300 thereon. In use, the boat 600 draws alongside the longline 500 and the longline is lifted (e.g. after snagging with a hook the longline may be subsequently mechanically or manually lifted) such that it engages both apparatuses 602, 602 (as will be described below). Once so positioned, the longline 500 is held aloft aside the boat 600, such that personnel on the boat can easily reach the tubes 300 depending therefrom. The spacing of the apparatuses 602, 602 at distal ends of the working area 604 ensures that the boat 600 remains substantially parallel to the long line 500, regardless of any wind or water currents that may be acting on the boat.

[0209] Referring more specifically to Figure 22, there is shown a magnified view of one of the retrieval apparatus 602. Apparatus 602 includes an arm 606 for engaging longline 500. The arm 606 is coupled to the boat 600 by a cantilever pivot 608 so it can be stowed when not in use (i.e. stowed apparatus 602 would not overhang the side of the boat). Apparatus 602 also includes line engagement means 610 for engaging the longline 500 in use. As is evident from the inward taper configuration of the line engagement means 610, the line engagement means 610 is adapted for frictional engagement of the longline 500 in use. Line engagement means 610 is rotatable such that the boat 600 can travel along the longline 500 (either using its own motor or via electric or hydraulic motors (not shown) within one or both of the apparatuses 602, 602), servicing the tubes 300 along the way.

[0210] The line engagement means 610 defines a space for engaging the longline 500 therein, the space being defined by an inner disk member 612 and an outer disk member 614. The inner disk member 612 may include one or more raised members (shown generally at 616) located on its inner face and adapted for frictional engagement of the longline 500 (i.e. in order to grip the longline 500 and draw the boat 600 therealong). The inner disk member 612 may also include edgewise located teeth, shown generally at 618 (see also Figure 21) for receiving and engaging one or more tethers 506 during use. In this manner, the teeth 618 provide gaps in which the tethers 506 are received, thereby ensuring that the tubes 300 (as well as any tethers securing the floats 504) are engaged by the inner disk member 612. In this manner, rotation of the inner disk member 612 causes the boat 600 to be drawn along the longline 500.

[0211] The retrieval apparatus 602 also has a line guidance means 620, which is a curved rail adapted to guide the longline 500 towards and onto the line engagement means 610 in use. The line guidance means 620 also guides the tethers 506 for the tubes 300 and floats 504 between the line guidance means 620 and the boat 600 to reduce the risk of the tethers 506 becoming tangled within the line guidance means 620. The line guidance means 620 extends forwardly towards the bow and rearwardly towards the stern of the boat 600.

[0212] In use, a boat 600 with retrieval apparatuses 602, 602 is sent at periodic intervals to feed, maintain, inspect or collect the tubes 300 suspended from the longline 500. The boat 600 draws alongside the longline 500, lifts it up and then engages it into the line engagement means 610, 610. As the boat 600 moves along the longline 500, the tubes 300 hanging therefrom are lifted out of the water and up to a convenient position where they may be accessed from the edge of

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the boat 600 (as can be seen in Figure 21) for inspection and/or maintenance of the stock and tube. If necessary, the tubes 300 may be positioned on the working area 604, where they can be opened in order to inspect the abalone and conditions inside the tube. The line engagement means 610 is hydraulically rotated so as to draw the boat 600 along the longline 500 to repeat the process for each of the tubes 300 on the longline 500. Once all of the tubes 300 on a particular longline 500 have been inspected, the boat 600 may turn around and repeat the process for another longline (not shown). In this manner, it is possible to inspect a very large number of abalone-containing tubes 300 without necessarily requiring divers or having to do any heavy lifting. As would be appreciated, this would significantly lower the costs associated with off-shore abalone farming, as well as greatly increasing their efficiency.

[0213] The boat 600 may also be provided with storage areas (not shown) that may be used to store tubes 300 removed from the longline 500 because the abalone contained therein have completed their first or second off-shore growth period (described above) and need to be appropriately graded. Such a storage area could also be used to carry freshly loaded tubes 300 containing abalone ready for their first or second off-shore growth period.

[0214] As described herein, the present invention provides improved abalone farming apparatus and methods. Embodiments of the present invention provide a number of advantages over existing abalone farming apparatus and methods, some of which are summarised below.

[0215] The tanks of the present invention may, for example, be advantageous because:

- providing the tank in a modular form can simplify the construction of such tanks;
- concrete slabs manufactured in a controlled environment are often less prone to defects (e.g. cracking, deforming, etc.) than is the case when constructed in situ;
- modular tanks can easily be installed on piers, which dispenses with the need for foundations.

[0216] The submersible container of the present invention may, for example, be advantageous because:

- abalone are safely contained therein, in an environment where predators are unlikely to be able to access them;
- it may be possible to inspect abalone stocks on only a monthly basis;
- the containers may be easy to inspect, retrieve and deploy without the need for divers or other complicated and expensive underwater equipment; and

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- the folded member located in a suspended position inside the container greatly increases the abalone carrying capacity of the container but, when unfolded, allows easy removal of abalone therefrom.

[0217] It will be understood to persons skilled in the art of the invention that many modifications may be made without departing from the spirit and scope of the invention. All such modifications are intended to fall within the scope of the following claims.

[0218] It will be also understood that while the preceding description refers to specific sequences of method steps, pieces of apparatus and equipment and their configuration to perform such methods in relation to particular applications, such detail is provided for illustrative purposes only and is not intended to limit the scope of the present invention in any way.

[0219] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

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CLAIMS:

1. A tank for growing abalone, the tank comprising:

   an elongate base comprising upright walls arranged substantially parallel to a longitudinal axis of the elongate base, and which define a channel therebetween for receiving a flow of water,

   wherein the elongate base comprises a plurality of prefabricated base portions adapted to be sealingly connected together, and

   whereby a length of the elongate base is defined by a length of two of the prefabricated base portions.

2. The tank of claim 1, wherein the elongate base comprises a plurality of channels.
3. The tank of claim 1 or claim 2, whereby a length of the elongate base is defined by a length of two of the prefabricated base portions.
4. The tank of any one of claims 1 to 3, wherein an edge of one of the prefabricated base portions comprises a protrusion configured to be sealingly received at a corresponding recess at an edge of another of the prefabricated base portions.
5. The tank of any one of claims 1 to 4, wherein an end of the elongate base is sealingly connectable to a water discharger for delivering the flow of water to the or each channel, and a distal end of the elongate base is sealingly connectable to a water drain.
6. The tank of claim 5, wherein the water discharger comprises a trough extending across a width of the elongate base, and whereby water delivered into the trough flows into the or each channel.
7. The tank of claim 5 or claim 6, wherein the water drain comprises a trough extending across a width of the elongate base, and whereby water that has flowed through the or each channel drains into the trough.
8. The tank of any one of claims 1 to 7, wherein the plurality of prefabricated base portions are substantially identical to one another.
9. A tank system comprising a plurality of the tanks of any one of claims 1 to 8, the plurality of tanks being arranged in an array.
10. The tank system of claim 9, comprising:

    two of the tanks of claim 1, wherein the tanks are arranged in-line along the longitudinal axis of their elongate bases and with an end of one tank positioned adjacent to an end of the other tank; and

    a central trough located between and sealingly connected to the elongate bases of the adjacent ends of the tanks, the central trough being selectively operable to either deliver a

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flow of water into the channels of the tanks or to drain water delivered into distal ends of the channels of the tanks.

11. The tank system of claim 10, further comprising an elevated platform above the central trough, the elevated platform adapted to receive a water receptacle thereon, the water receptacle being operable to deliver a water surge into one or more of the channels.
12. The tank system of claim 11, wherein the water receptacle is slidable along rails provided on the elevated platform such that it is in alignment with a selected one or more of the channels.
13. The tank of claim 11 or claim 12, wherein the water receptacle is pivotable towards either tank, whereby the water surge is deliverable to a selected one or more of the channels.
14. The tank system of any one of claims 9 to 13, further comprising an abalone feeding apparatus that is adapted to move along a length of each channel and broadcast food into the channel.

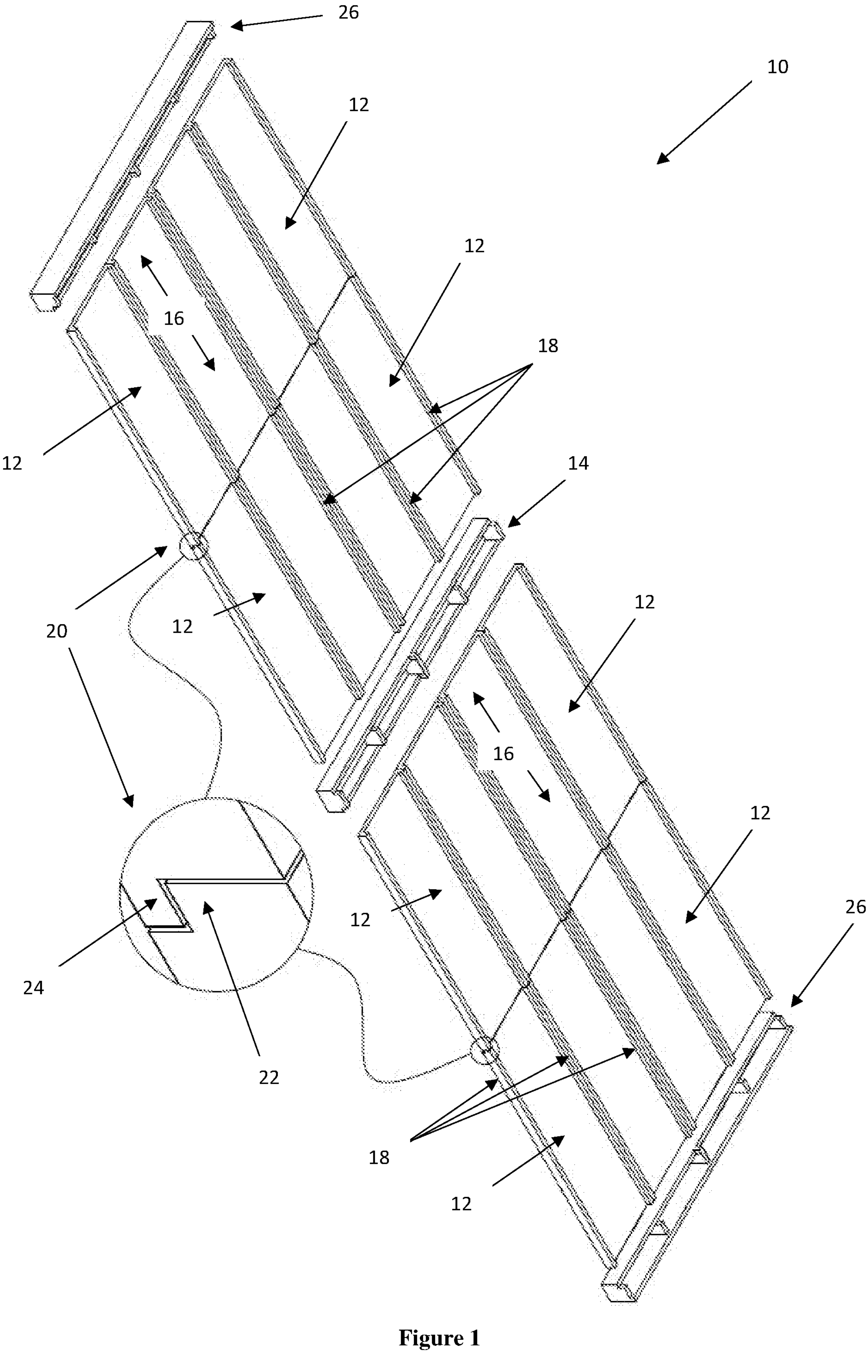

Figure 1

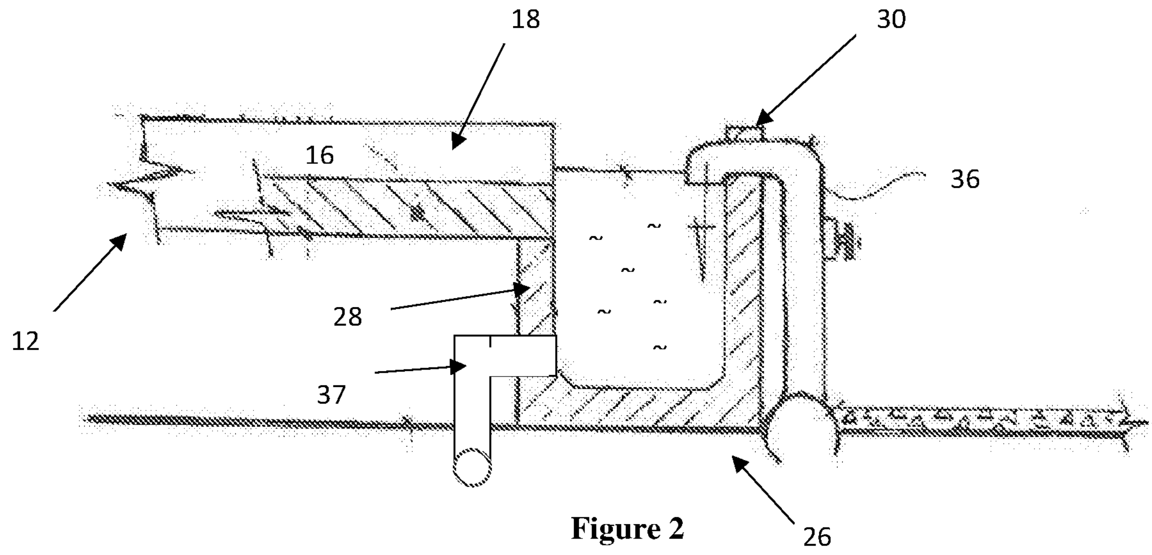

Figure 2

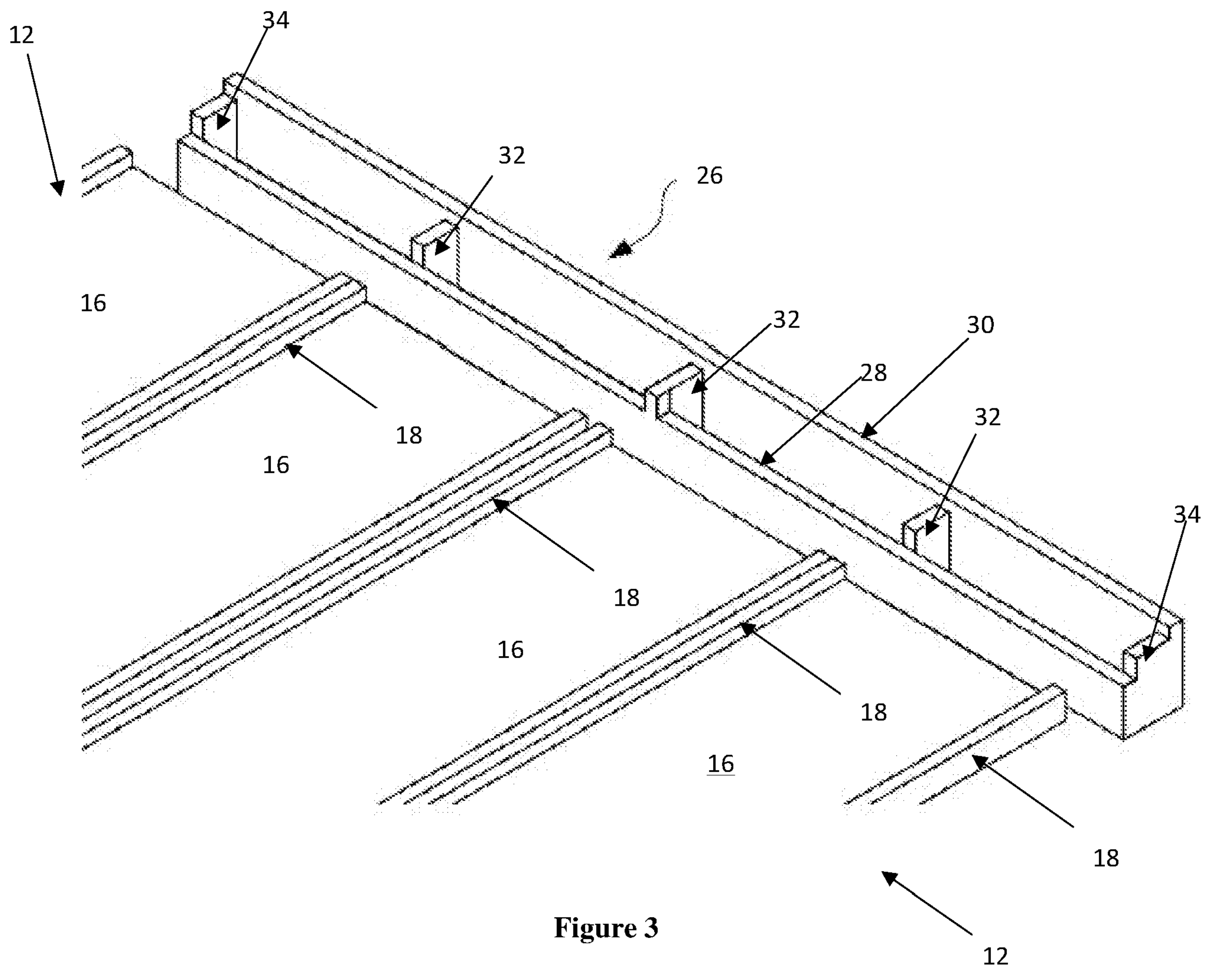

Figure 3

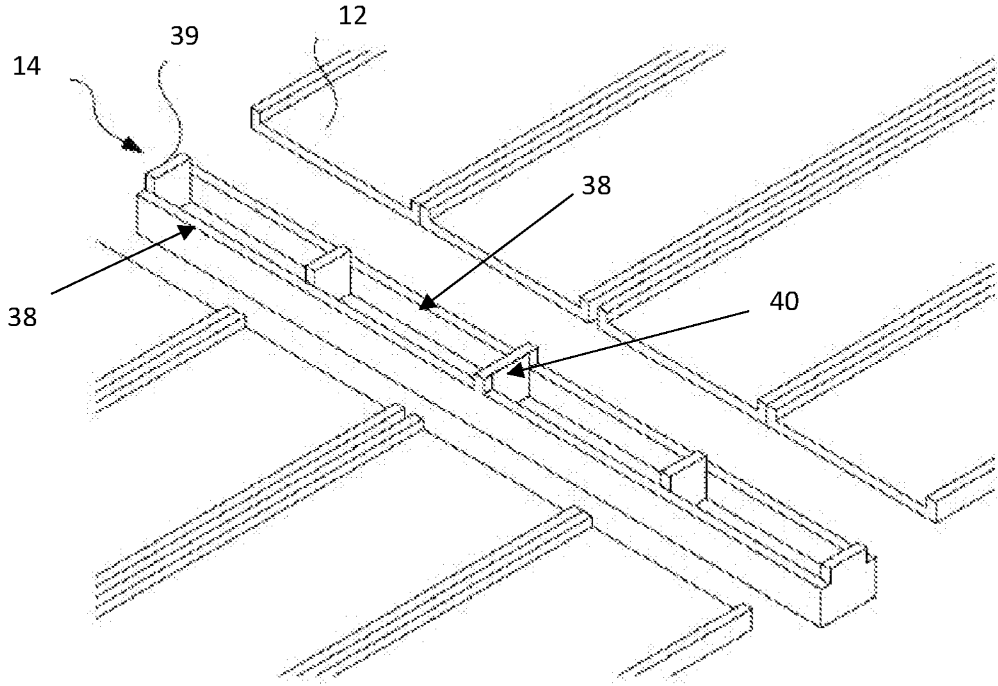

Figure 4

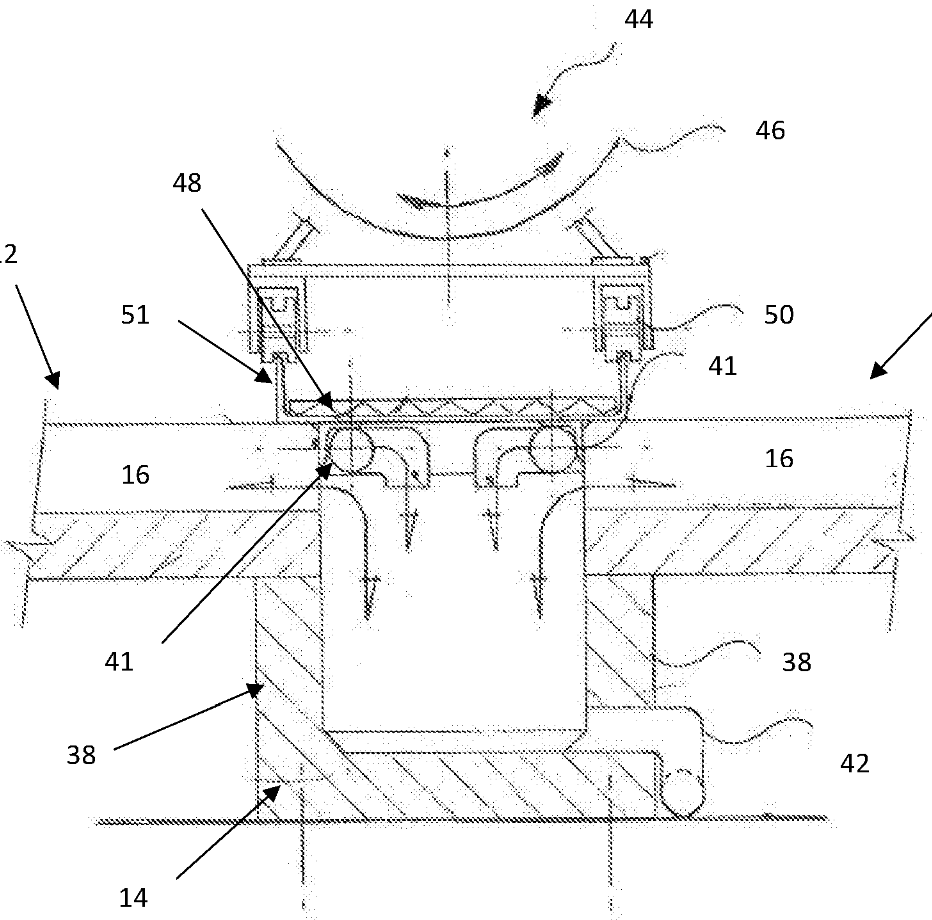

Figure 5

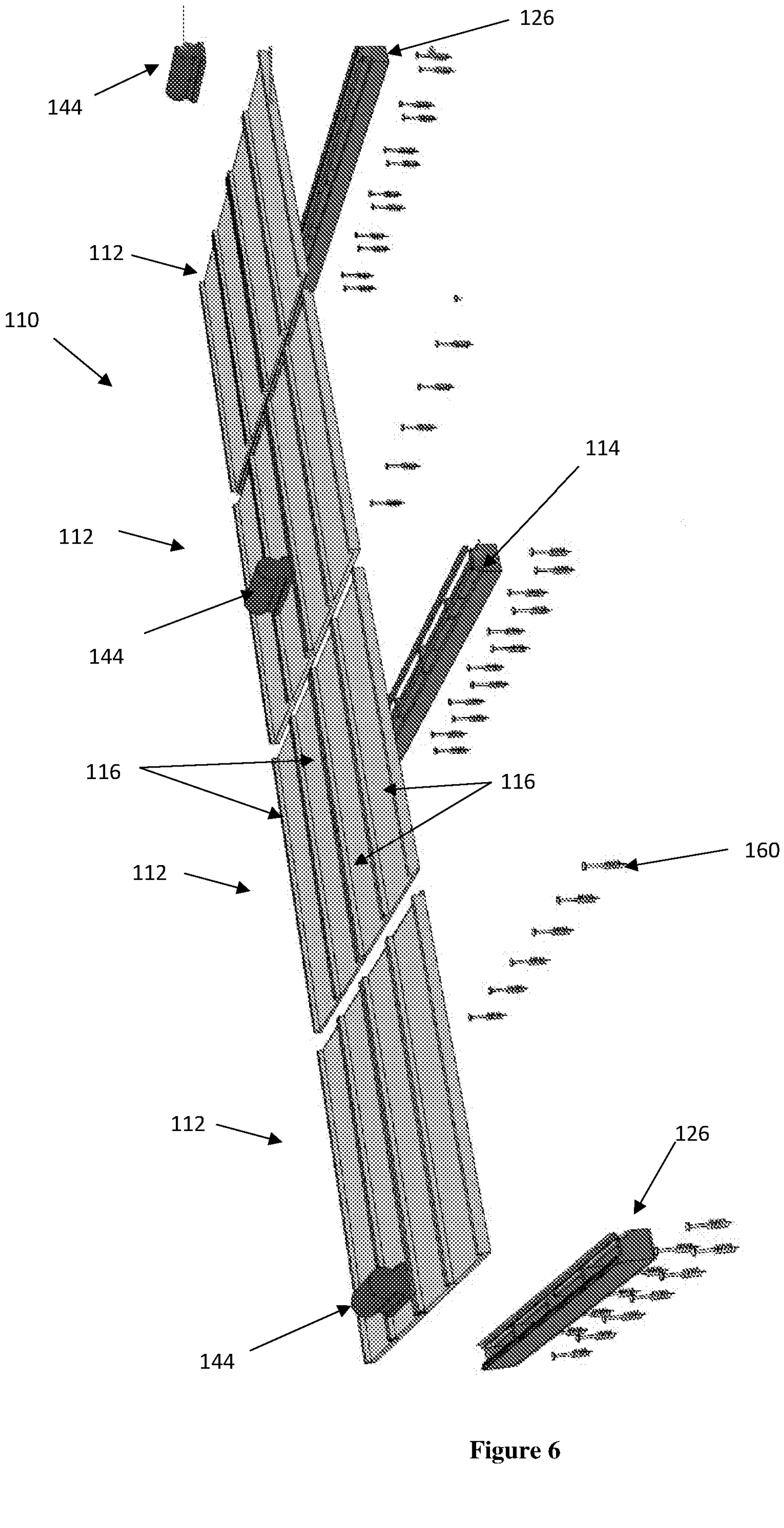

Figure 6

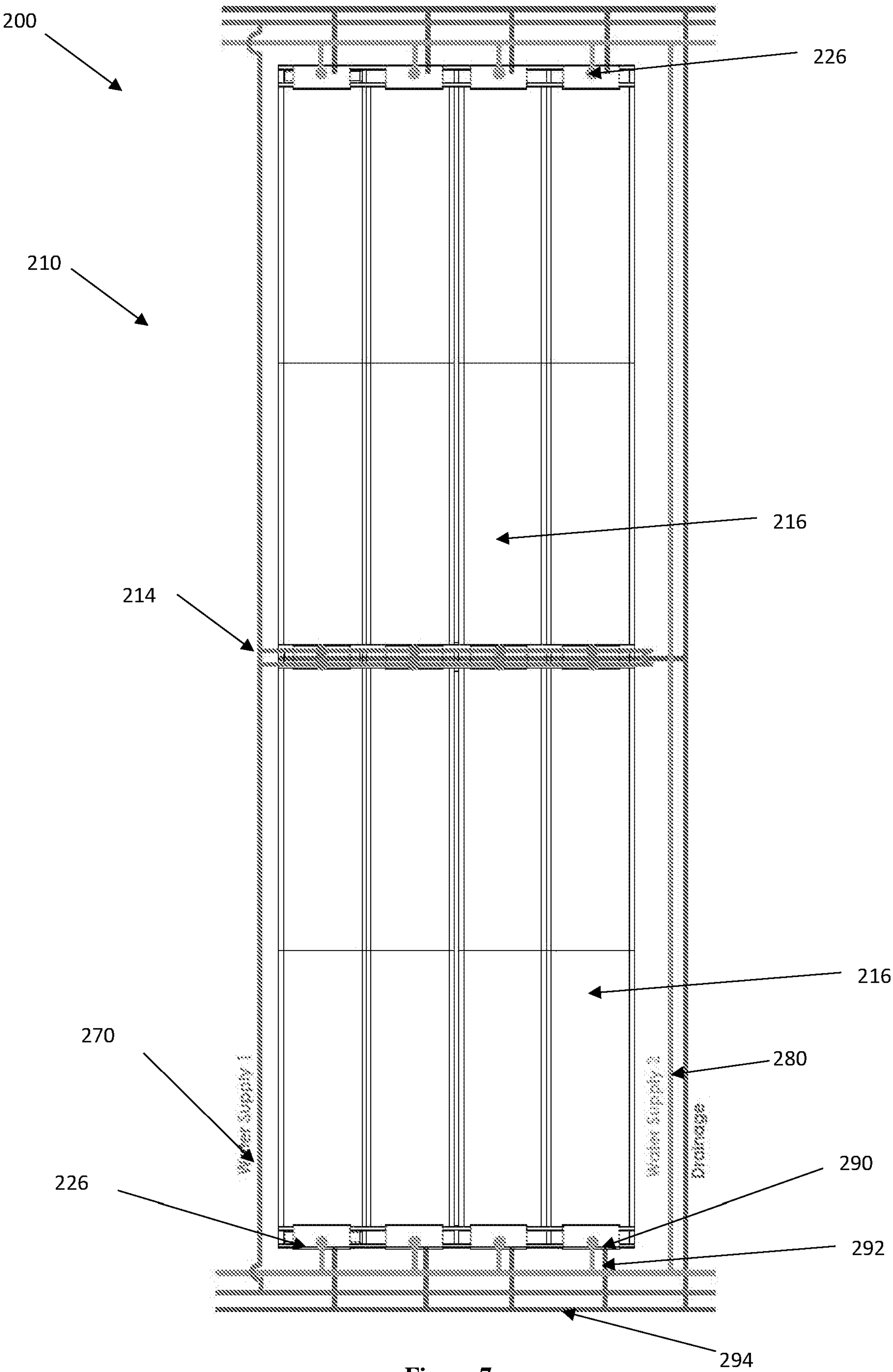
200
226
210
216
214
216
270
280
Water Supply 1
Water Supply 2
Drainage
226
290
292
294

Figure 7

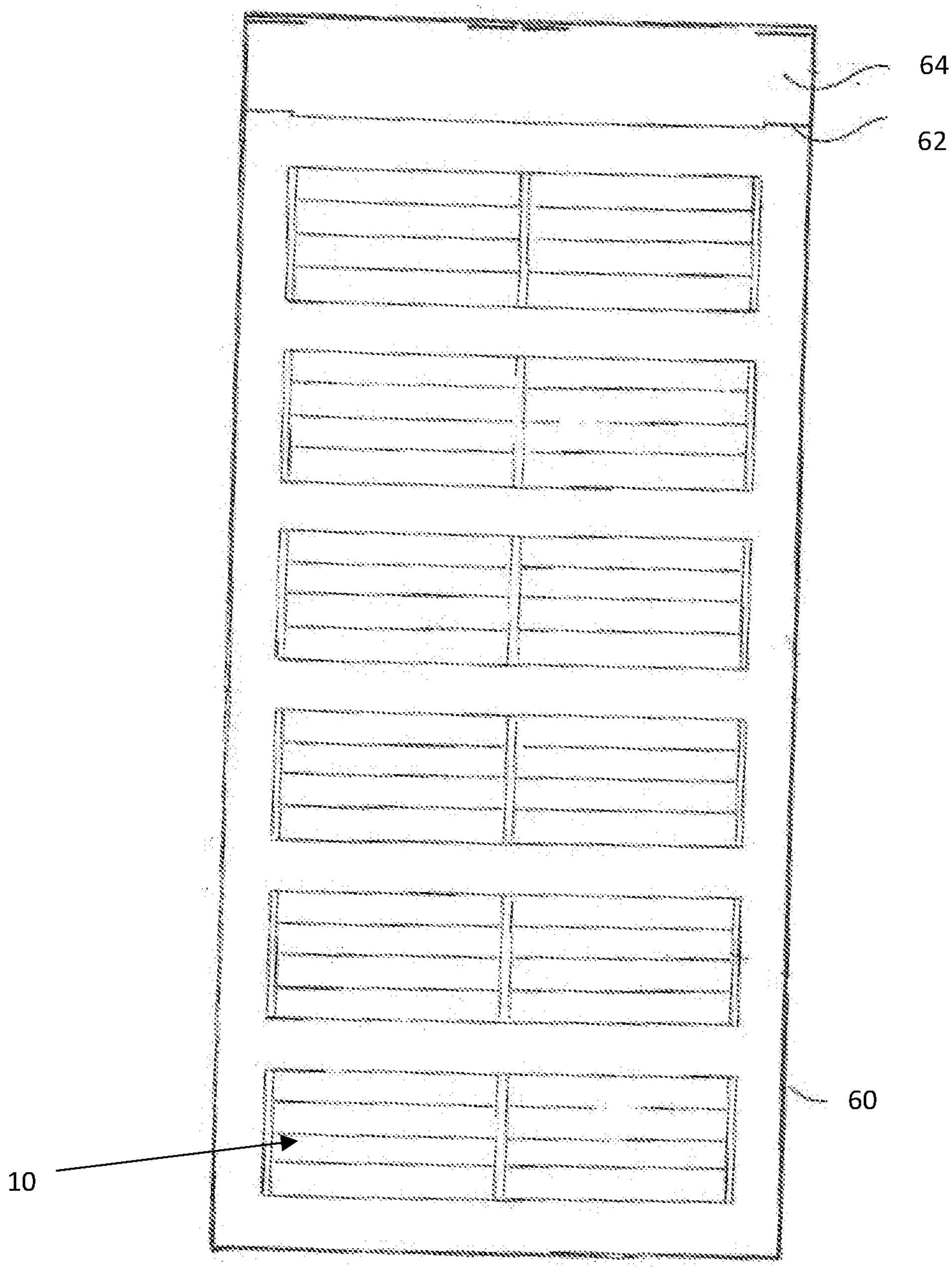

Figure 8

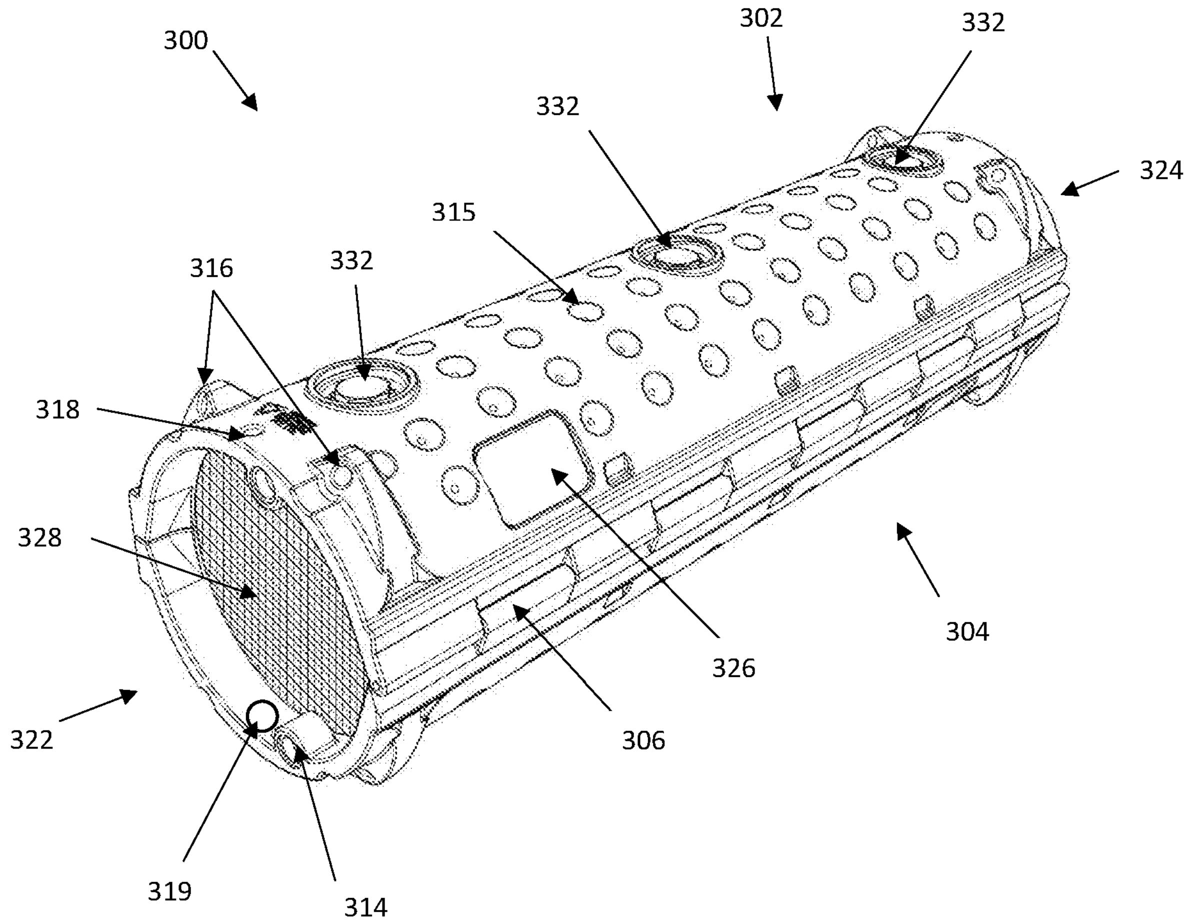

Figure 9

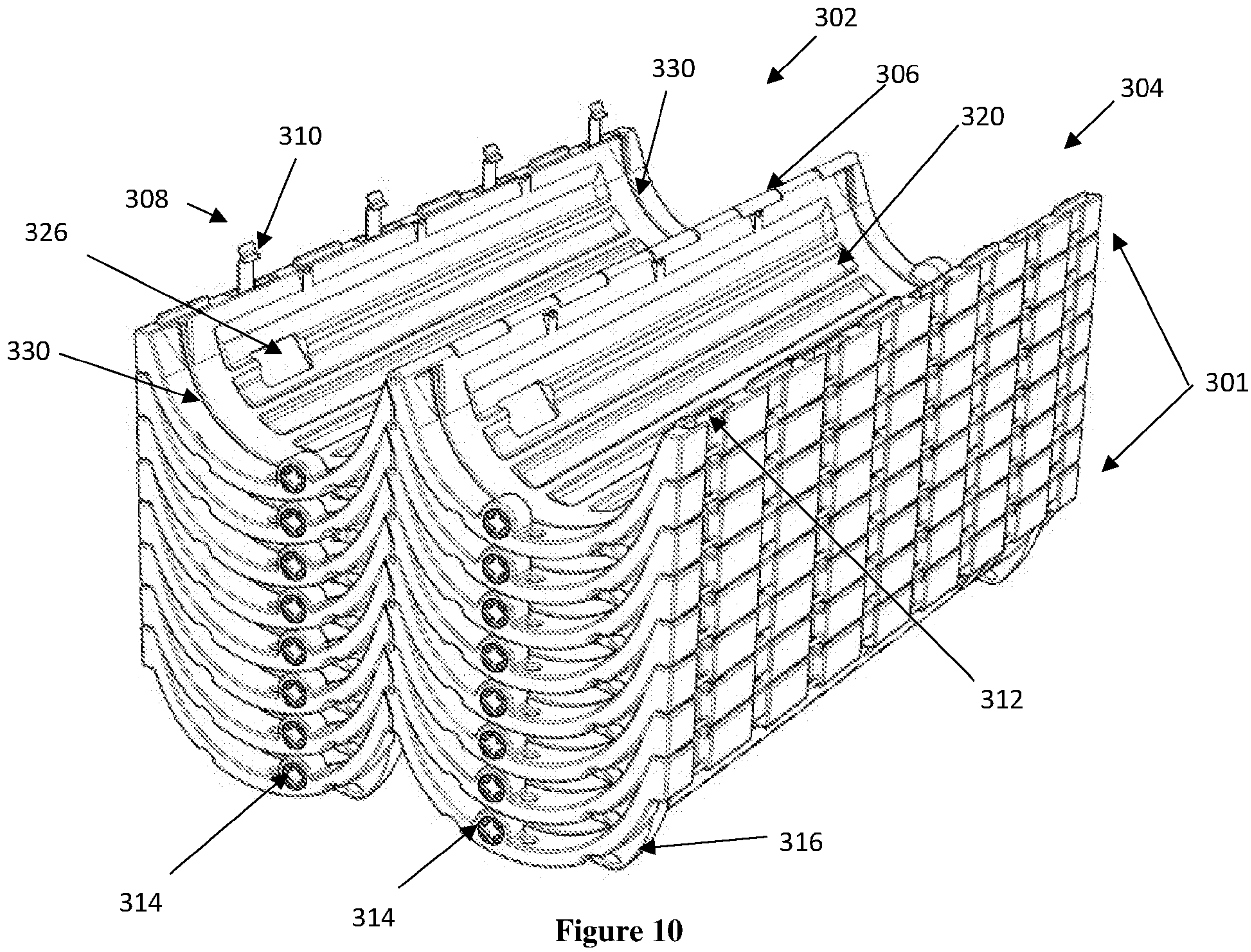

Figure 10

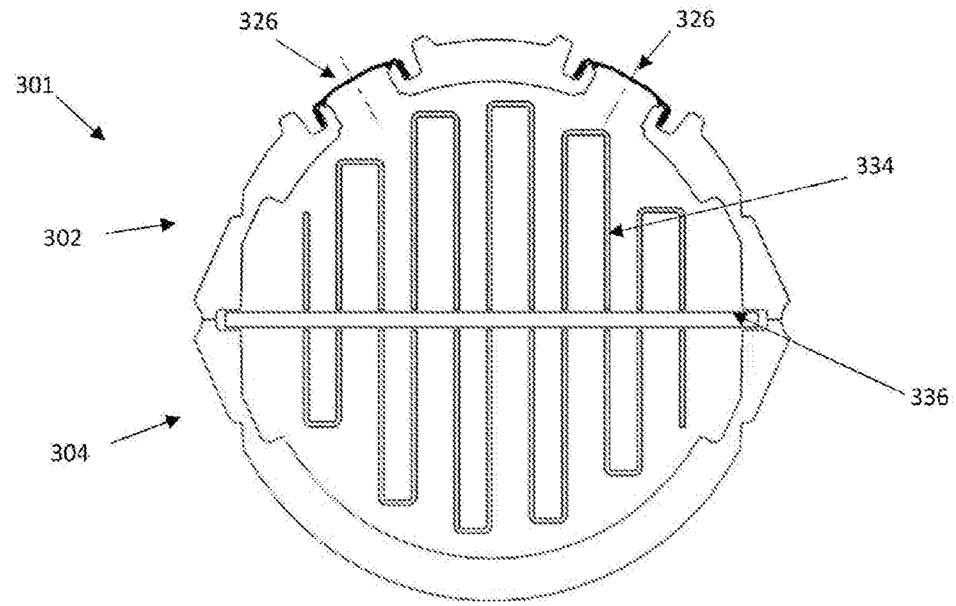

Figure 11

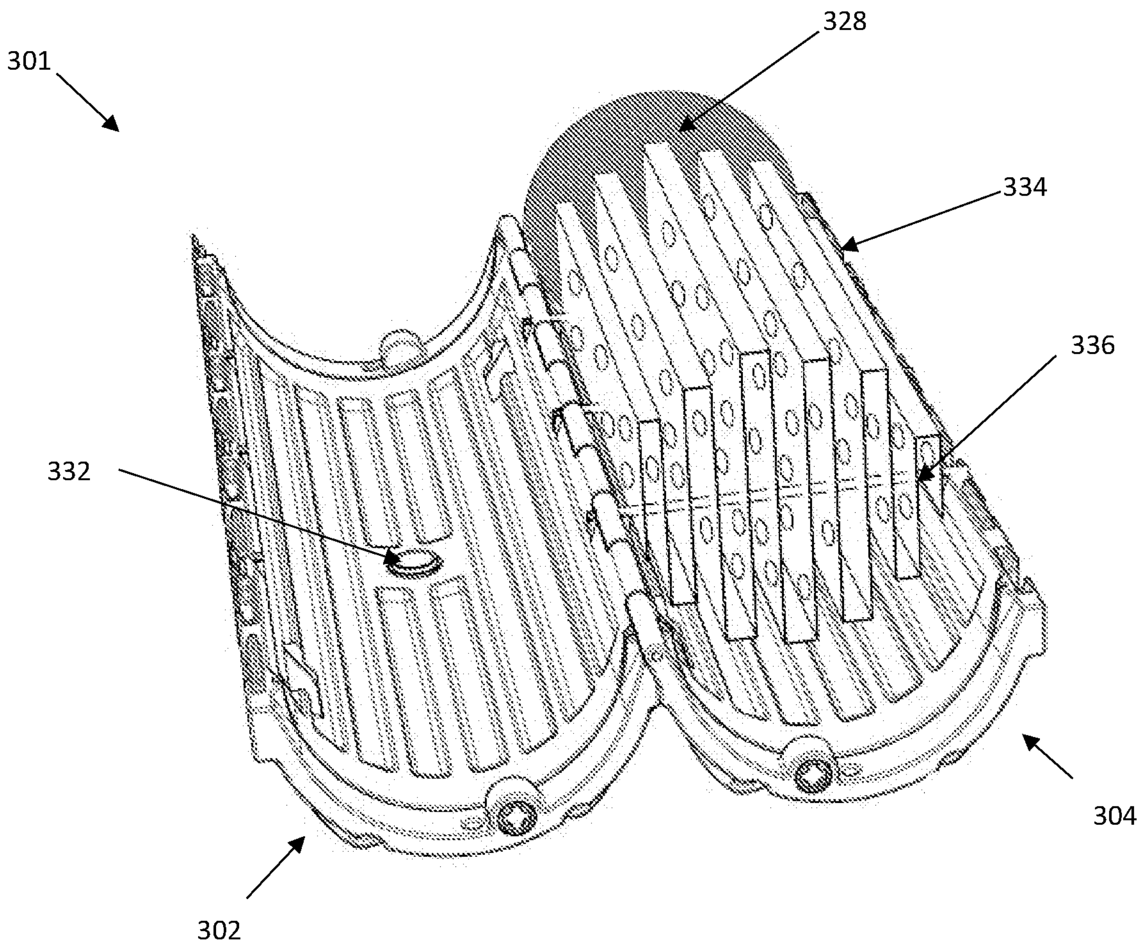

Figure 12

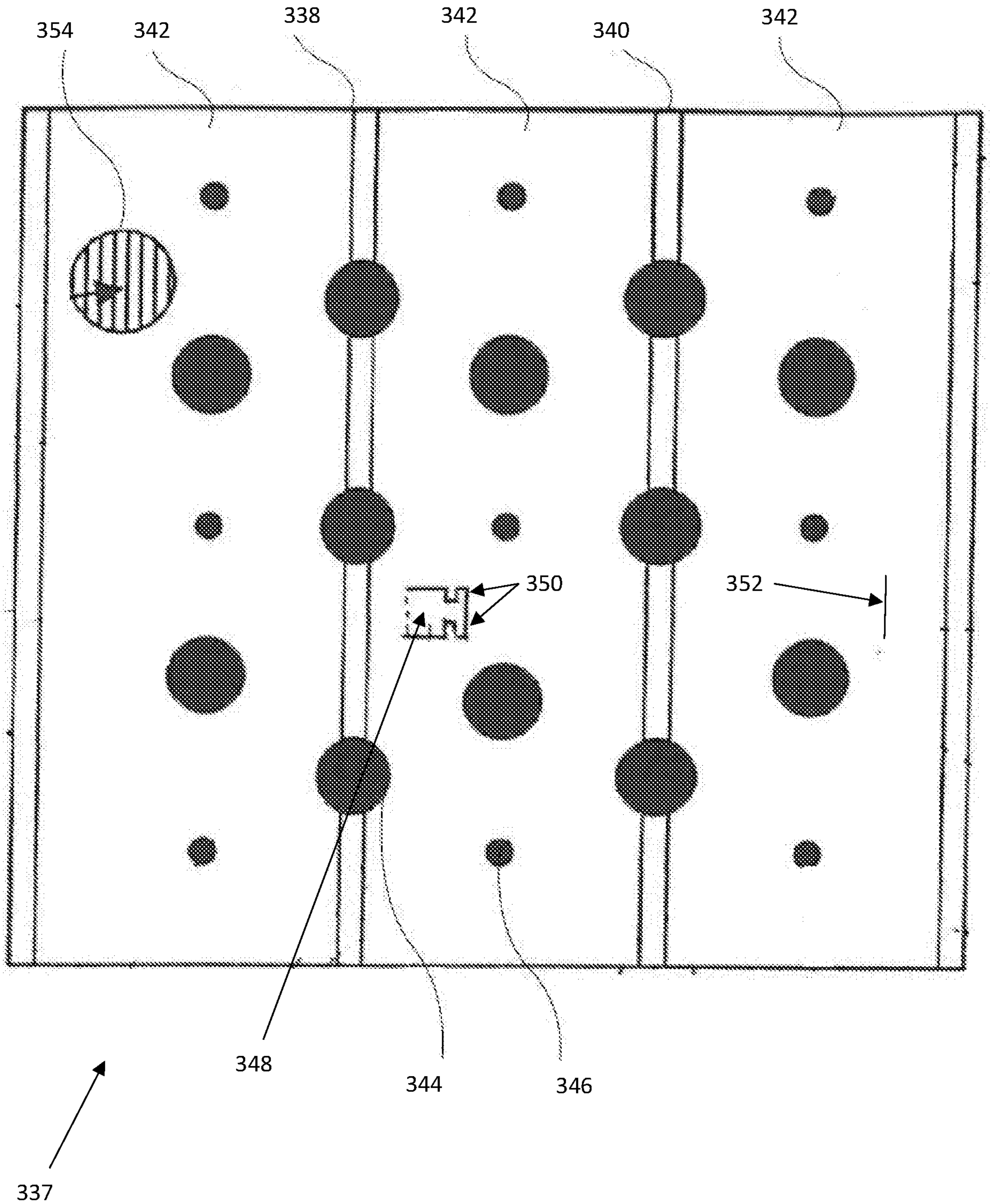

Figure 13

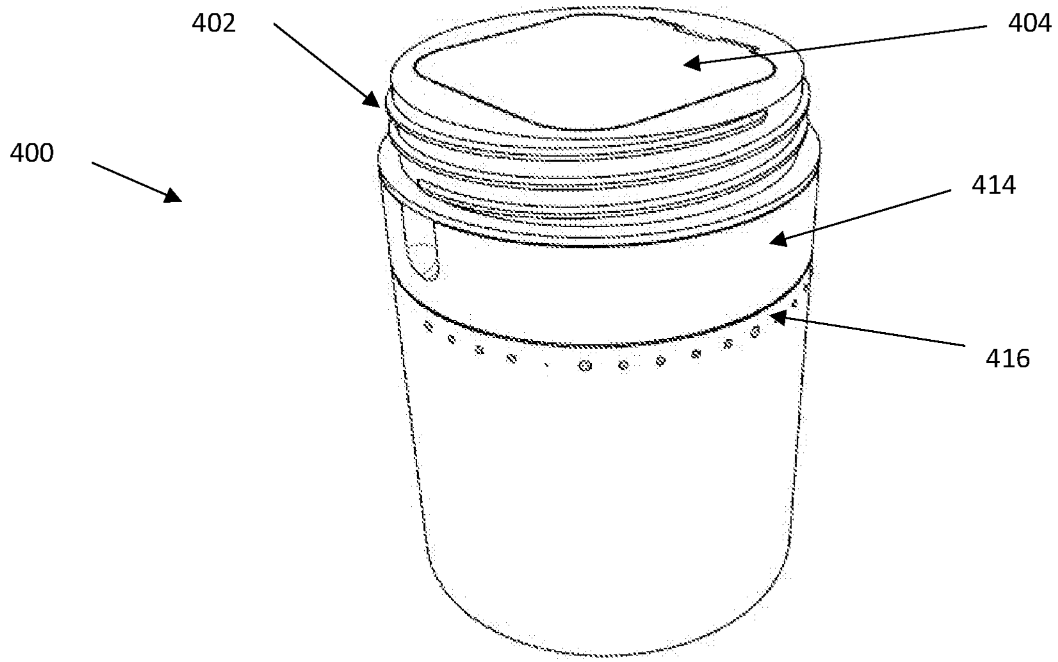

Figure 14

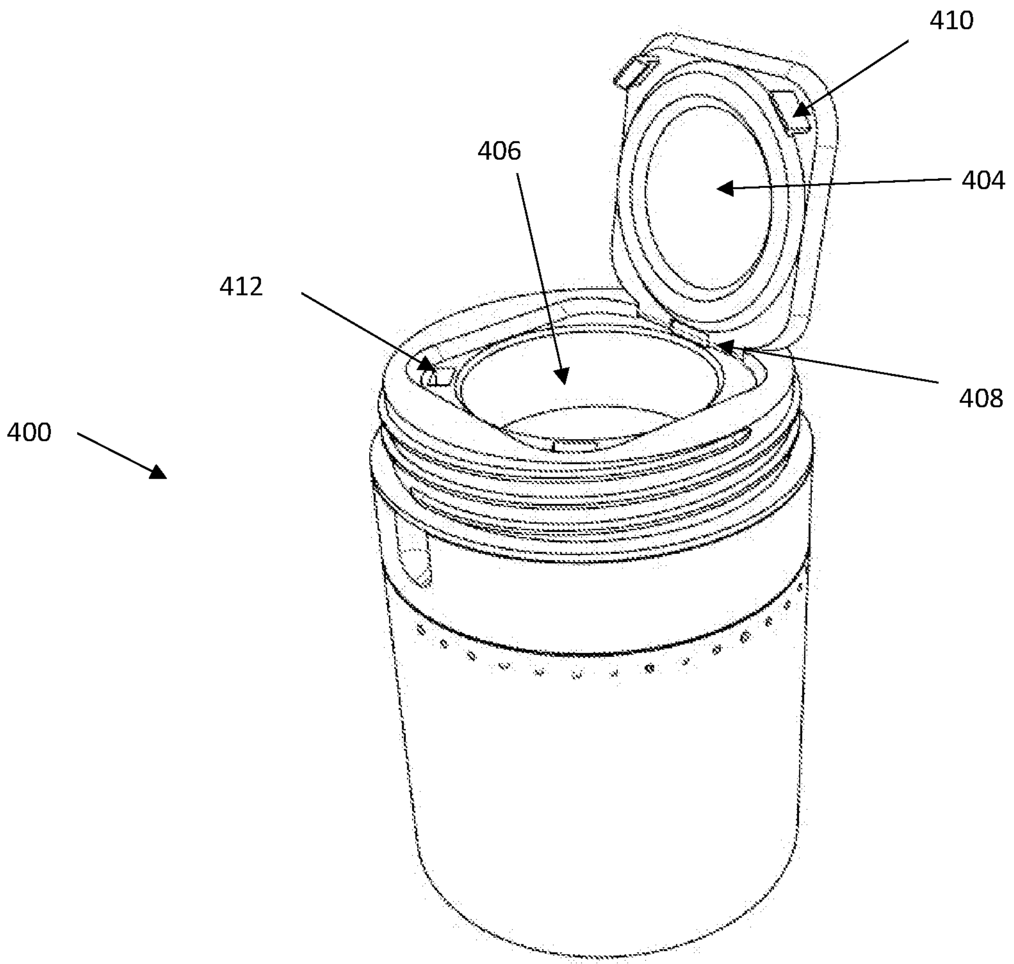

Figure 15

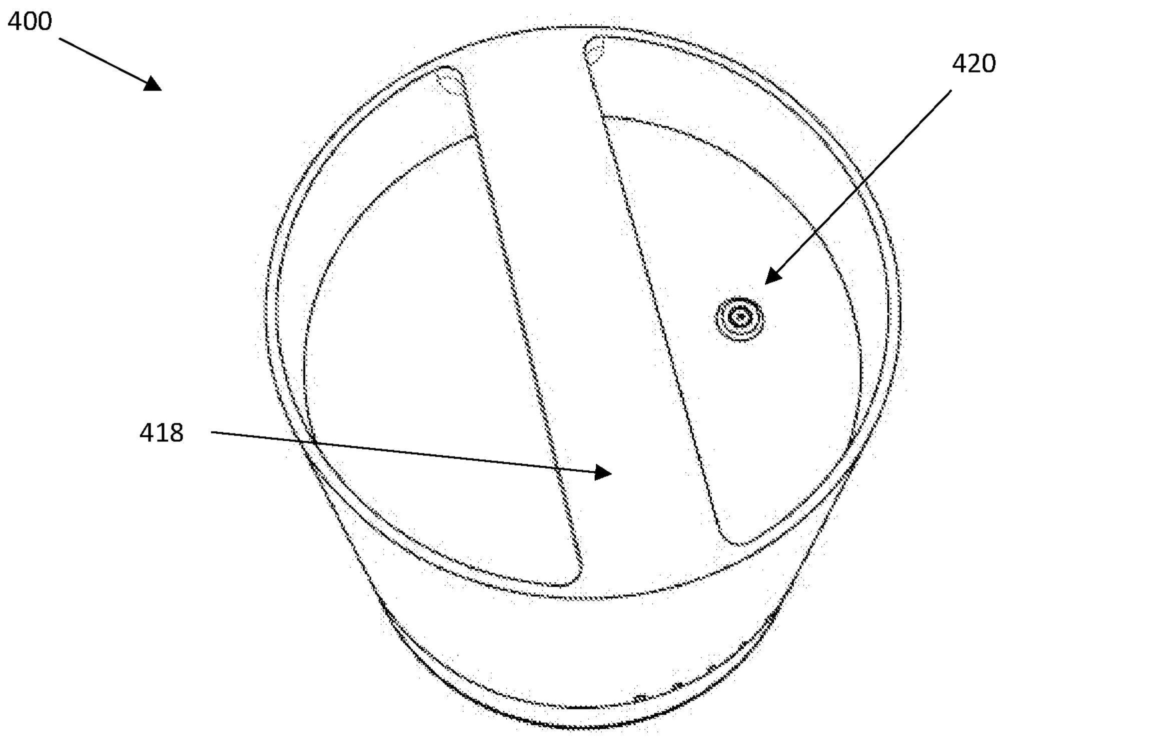

Figure 16

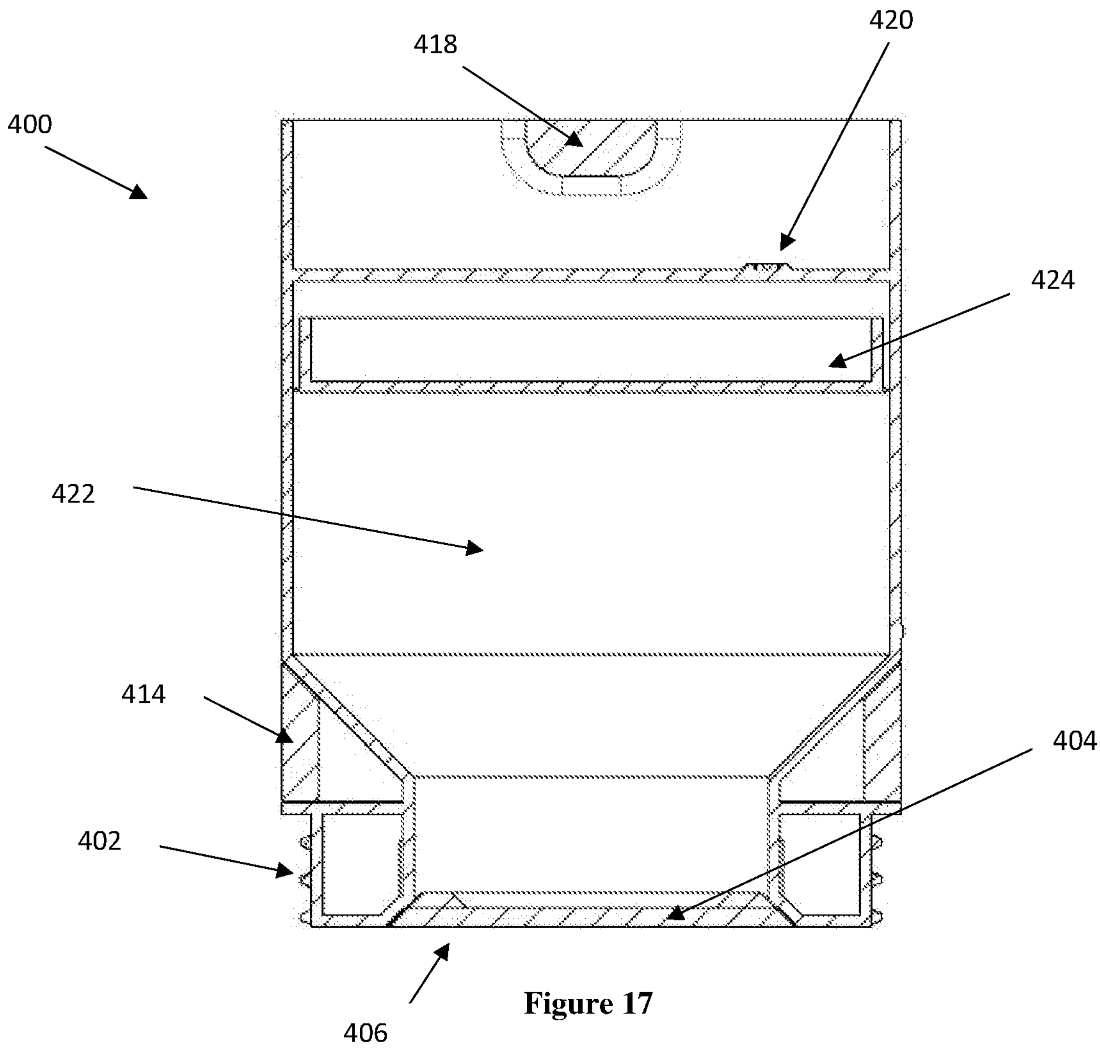

Figure 17

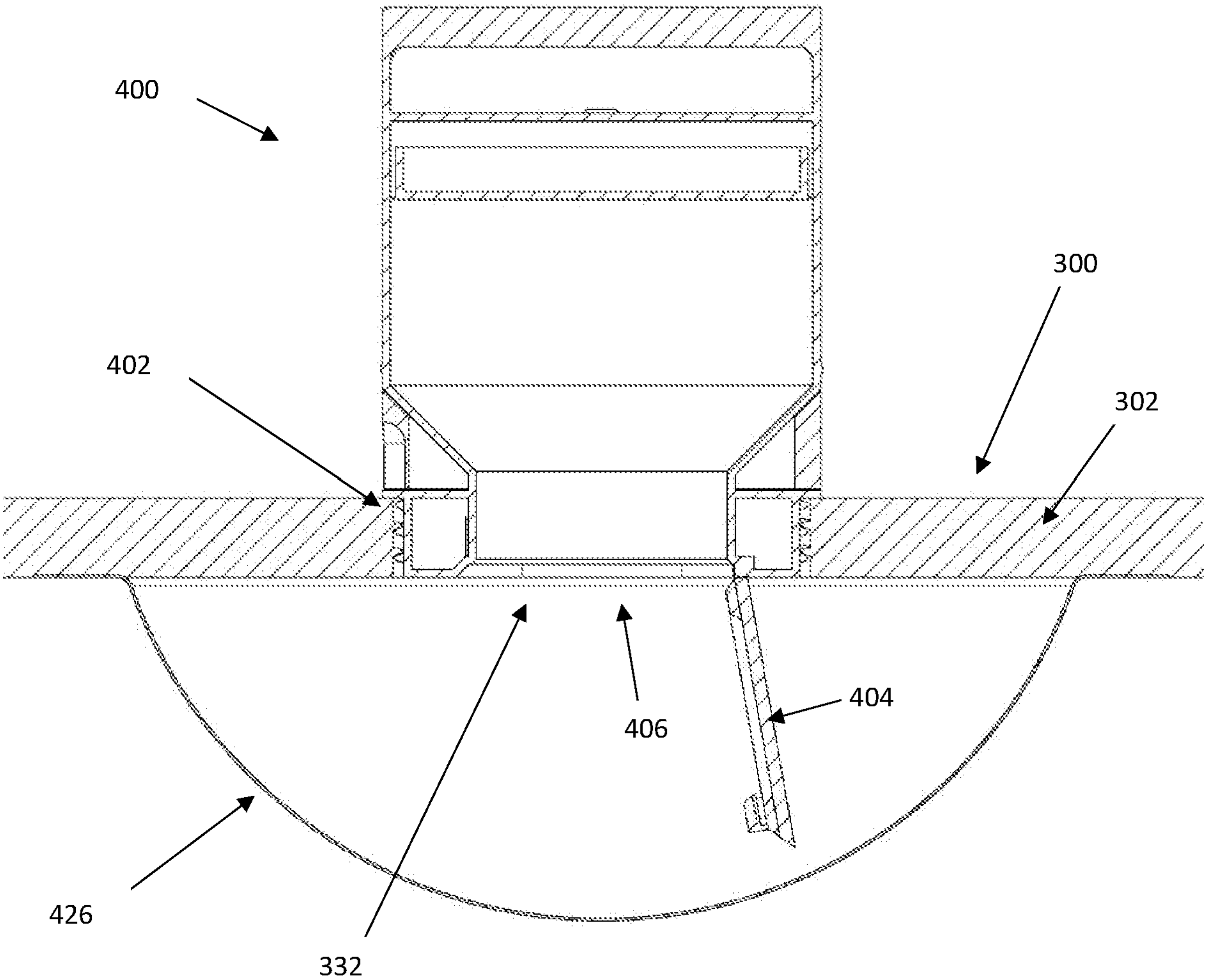

Figure 18

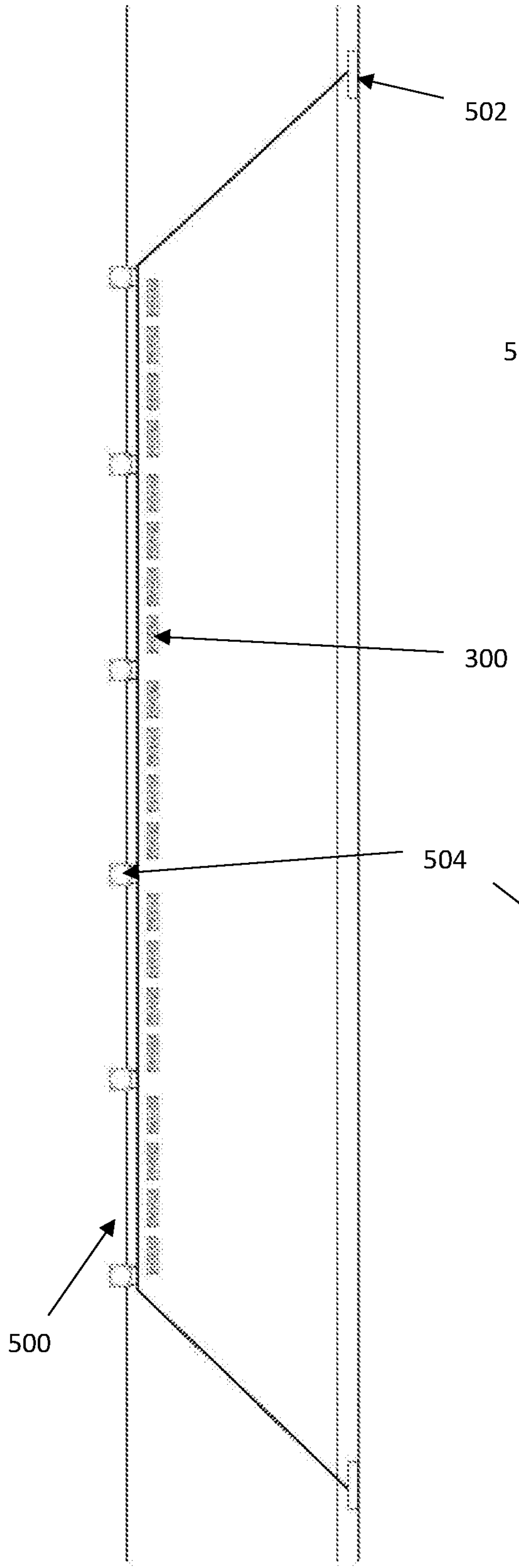

Figure 19

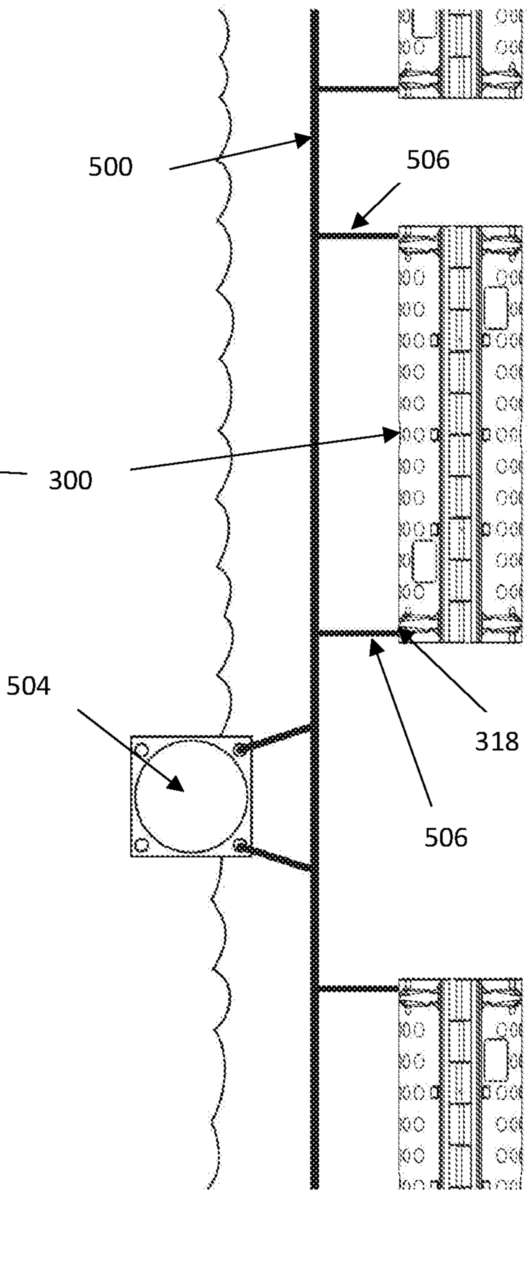

Figure 20

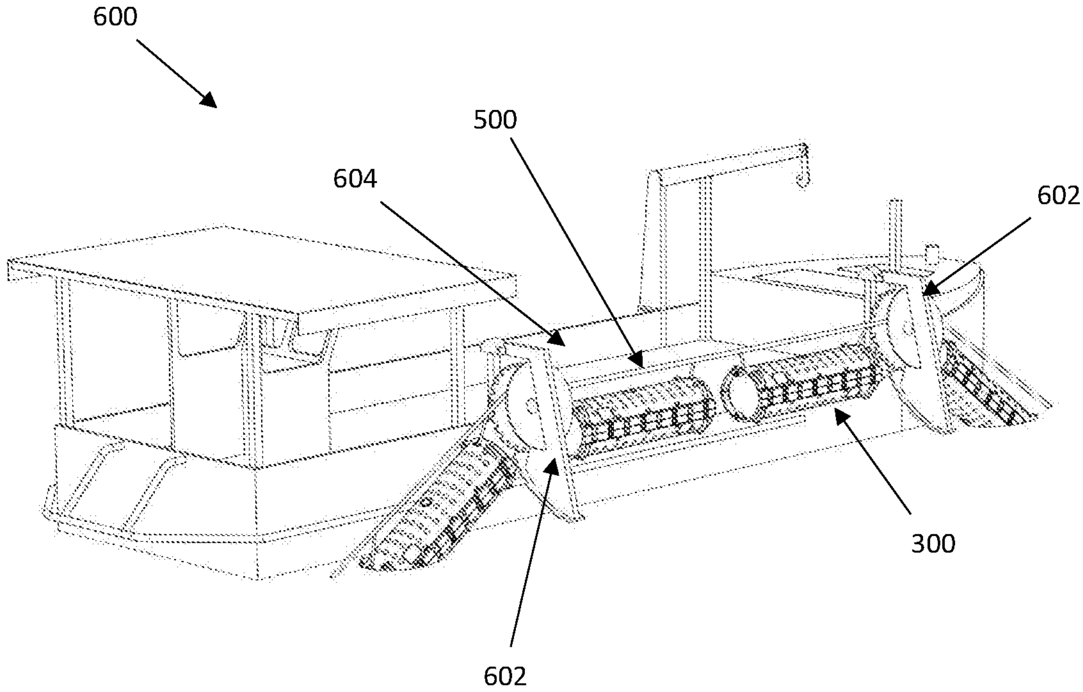

Figure 21

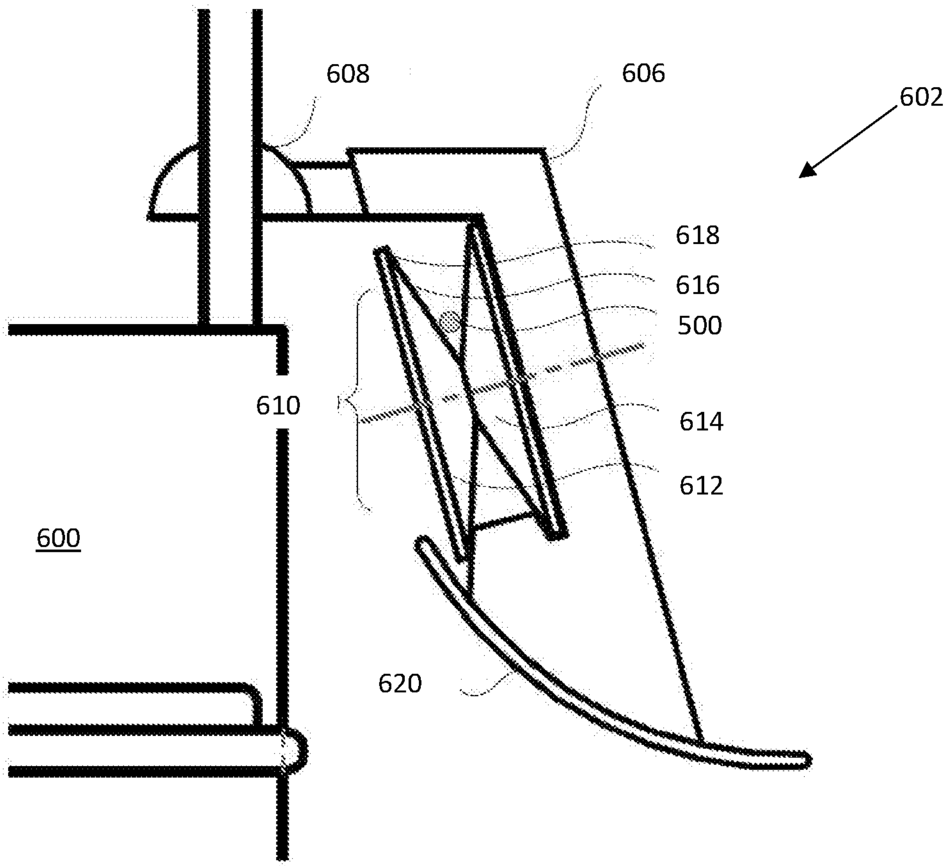

Figure 22