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(54) **AEROPONIC PLANT GROWING SYSTEM AND METHODS OF USE**

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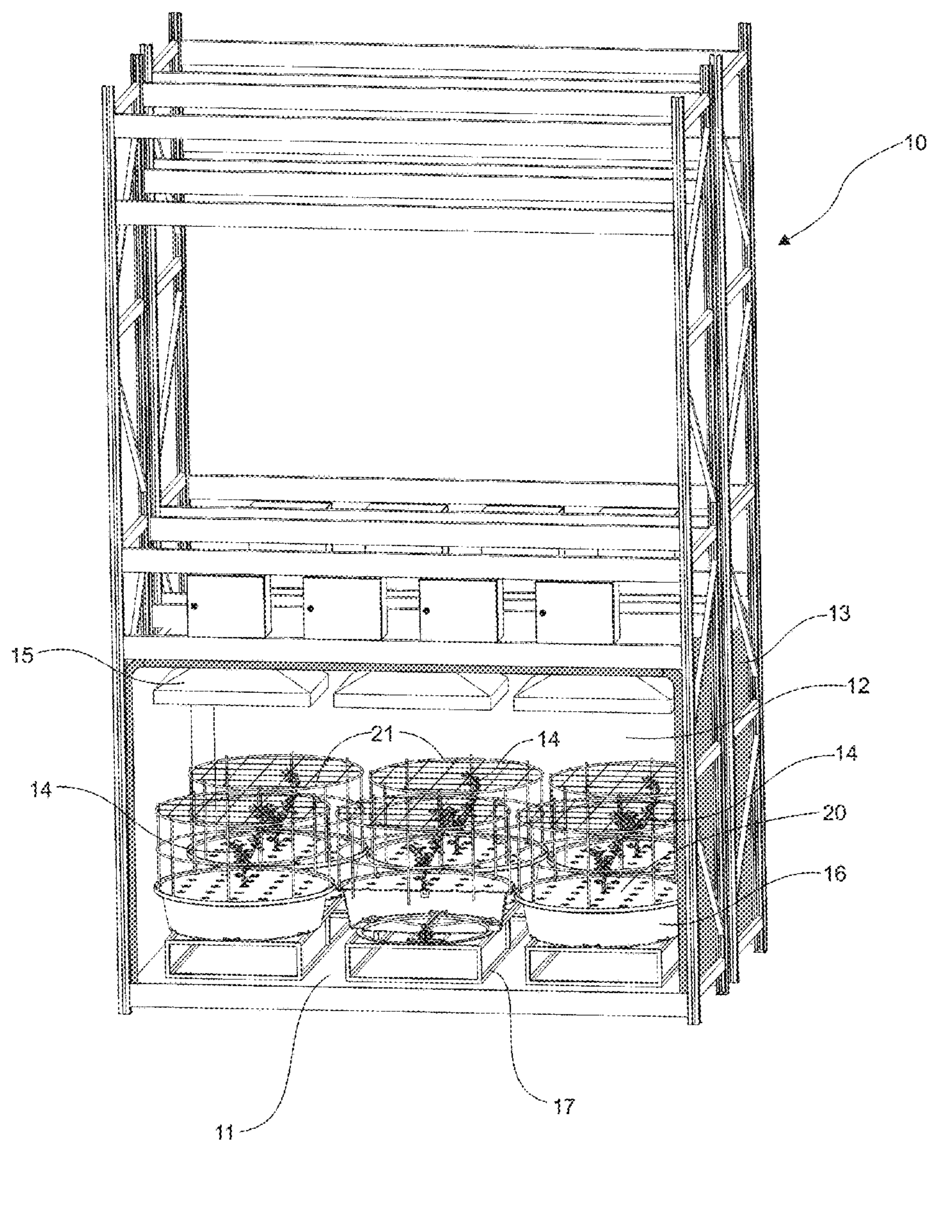
CPC ***A01G 31/02*** (2013.01); *A01G 2031/006* (2013.01); ***A01G 9/24*** (2013.01)

(57) **ABSTRACT**

Apparatus and methodologies for aeroponically growing a large crop of plants are provided, comprising at least one climate-controlled growth chamber containing a plurality of independently rotatable plant support structures for receiving and supporting a plurality of plants in close proximity to one another, providing easy access to the plants within the growth chamber without interruption delivery of a nutrient-rich solution to the plants. Where desired, each plant support structure may also be quickly and easily removed from the growth chamber, via at least one quick-release mechanism.



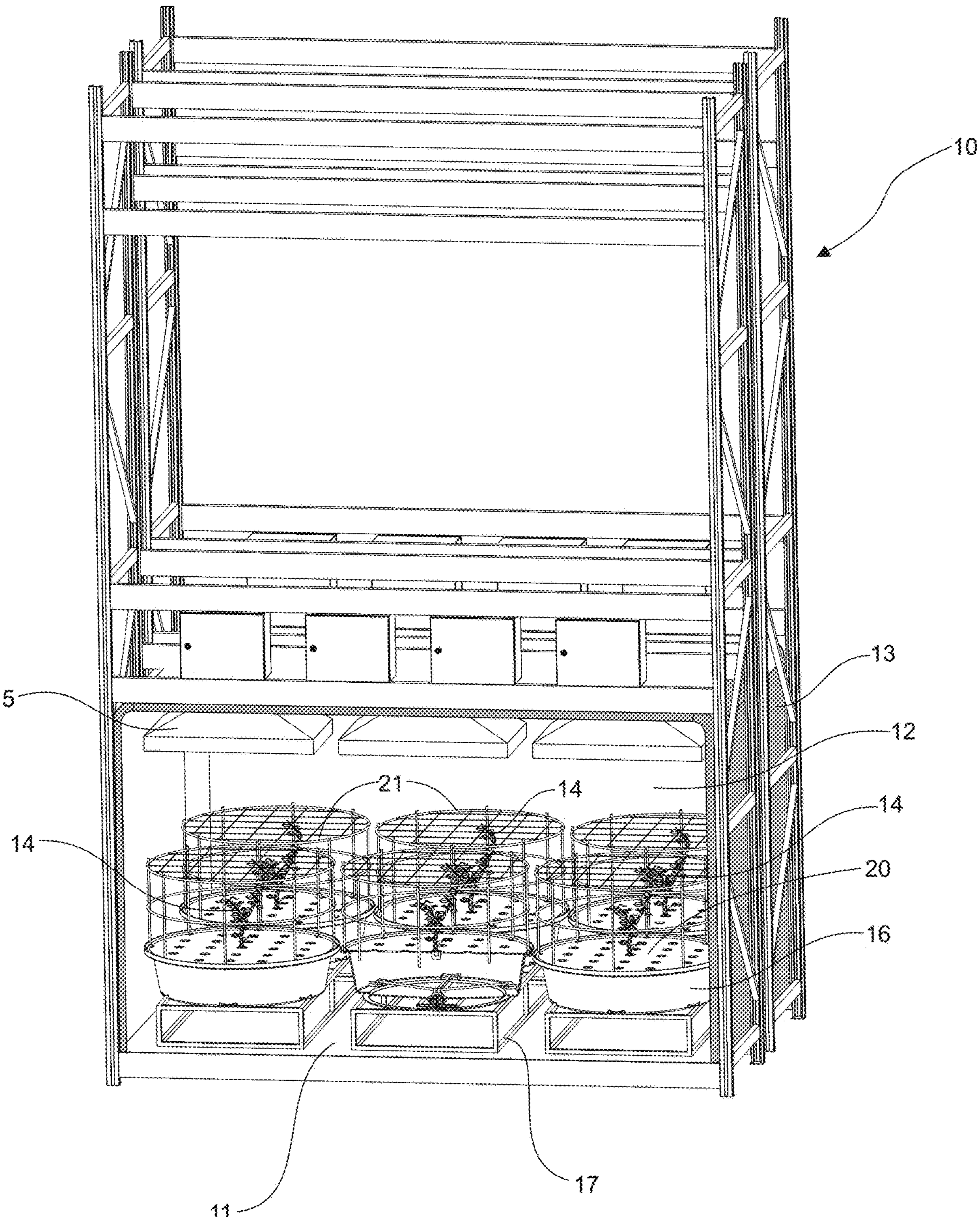


Fig. 1

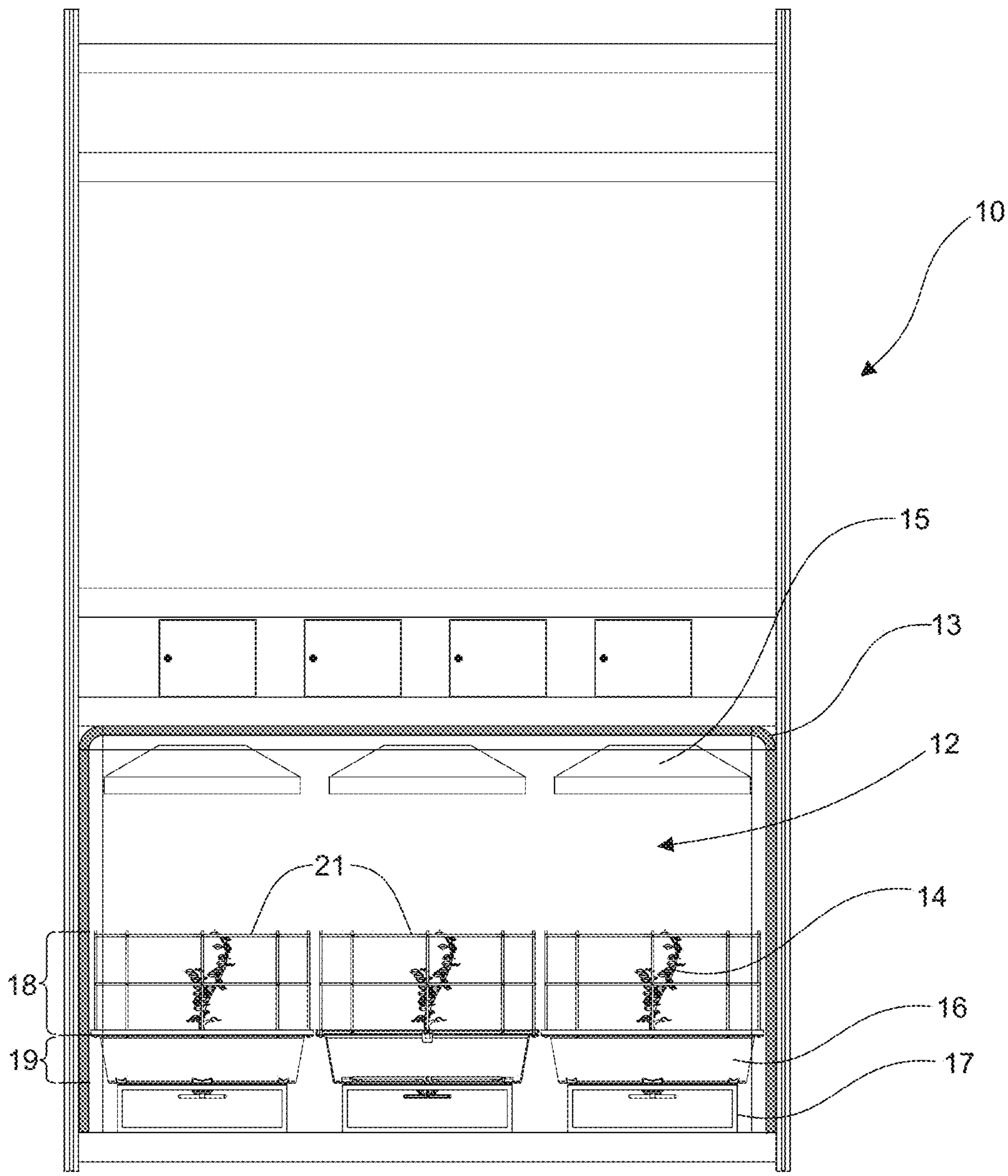


Fig. 2

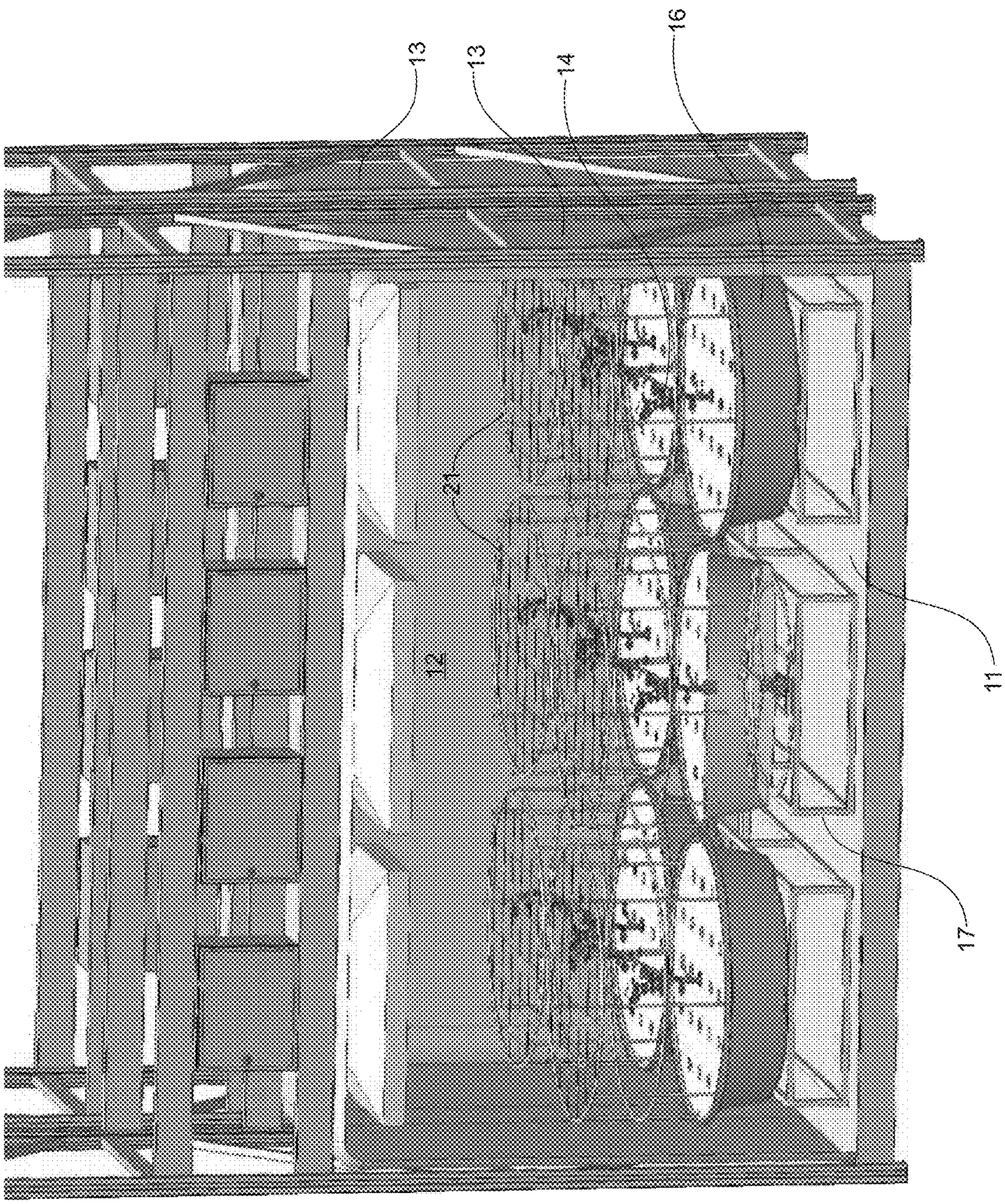


Fig. 3

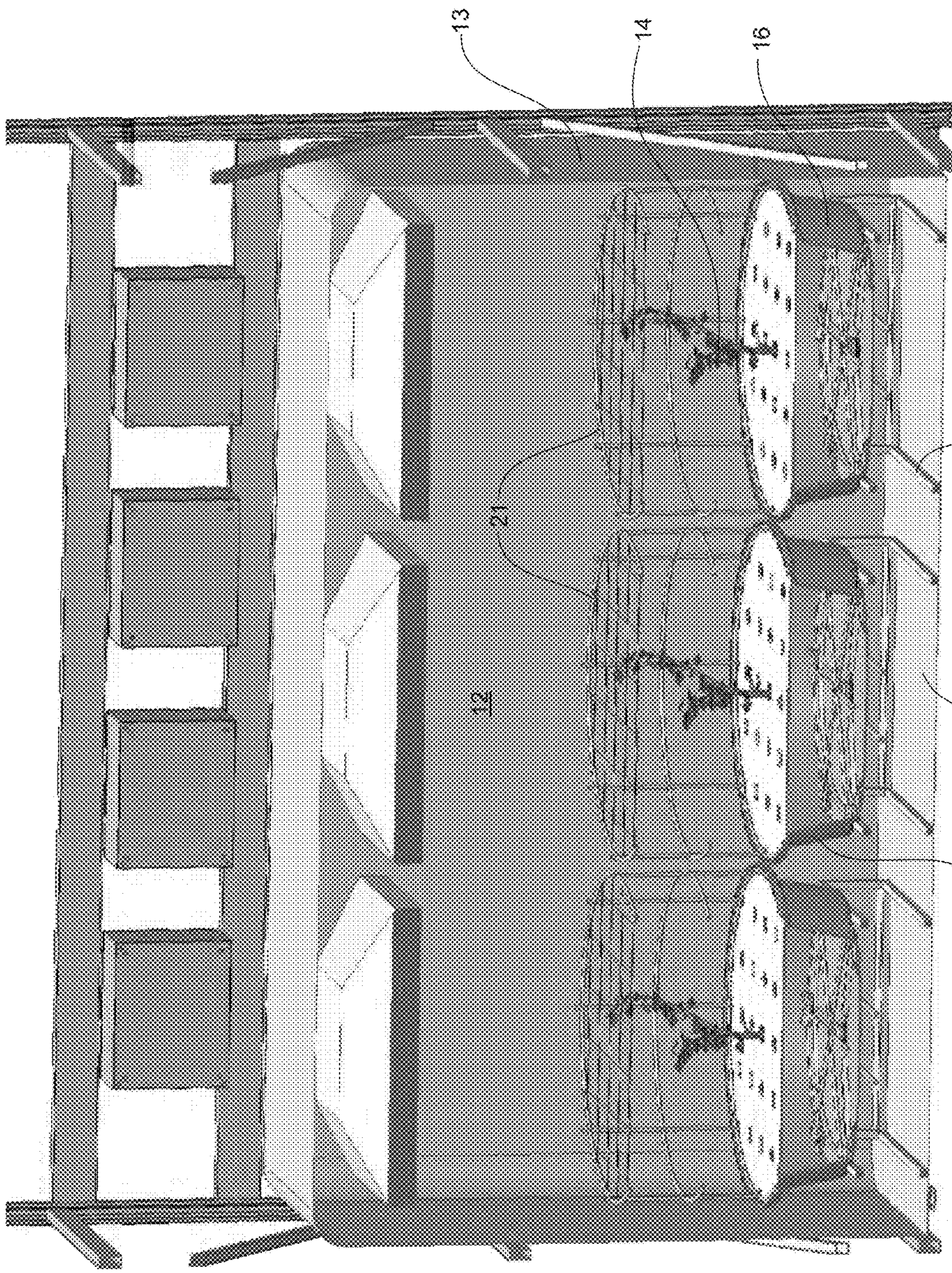


Fig. 4

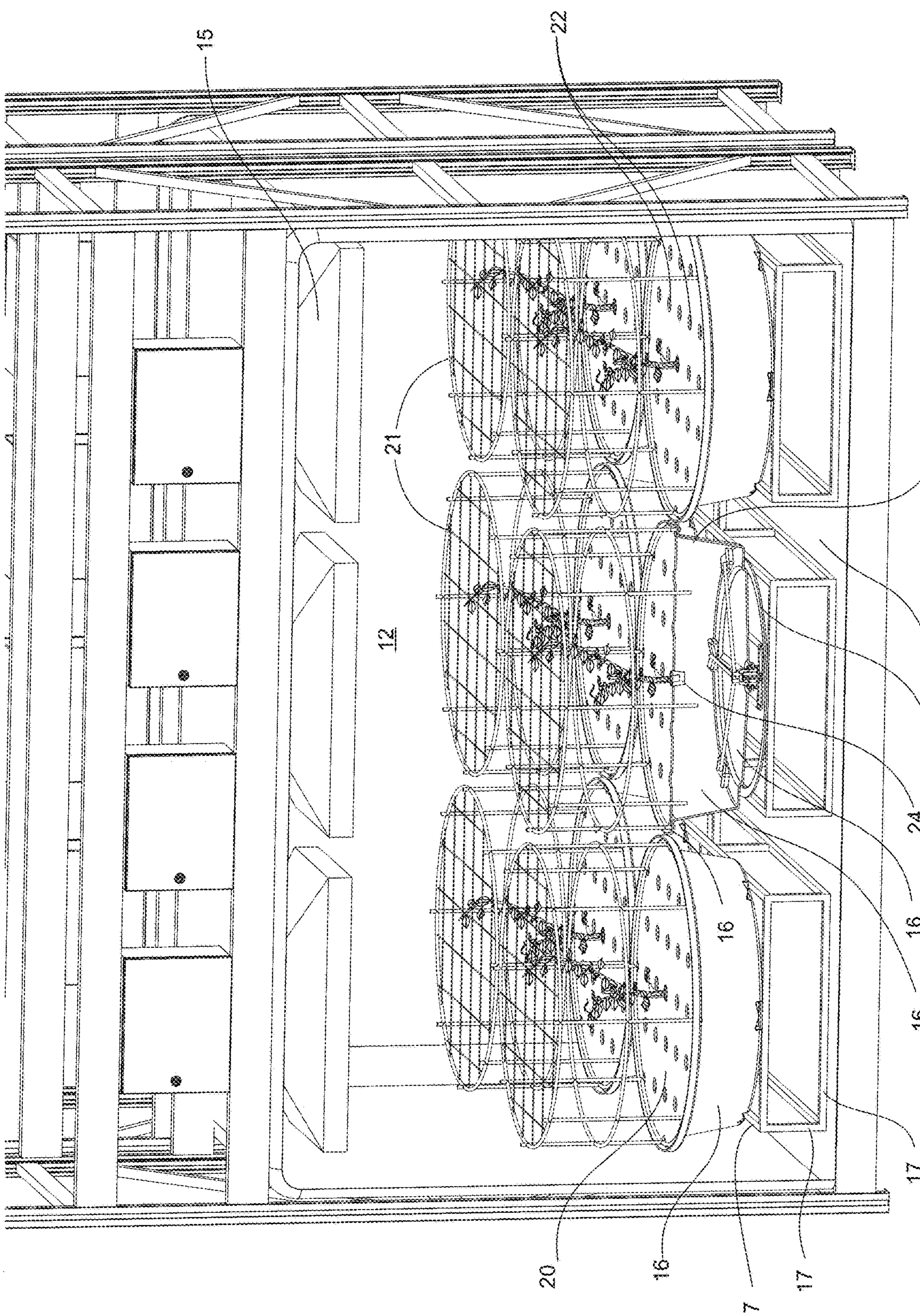


Fig. 5

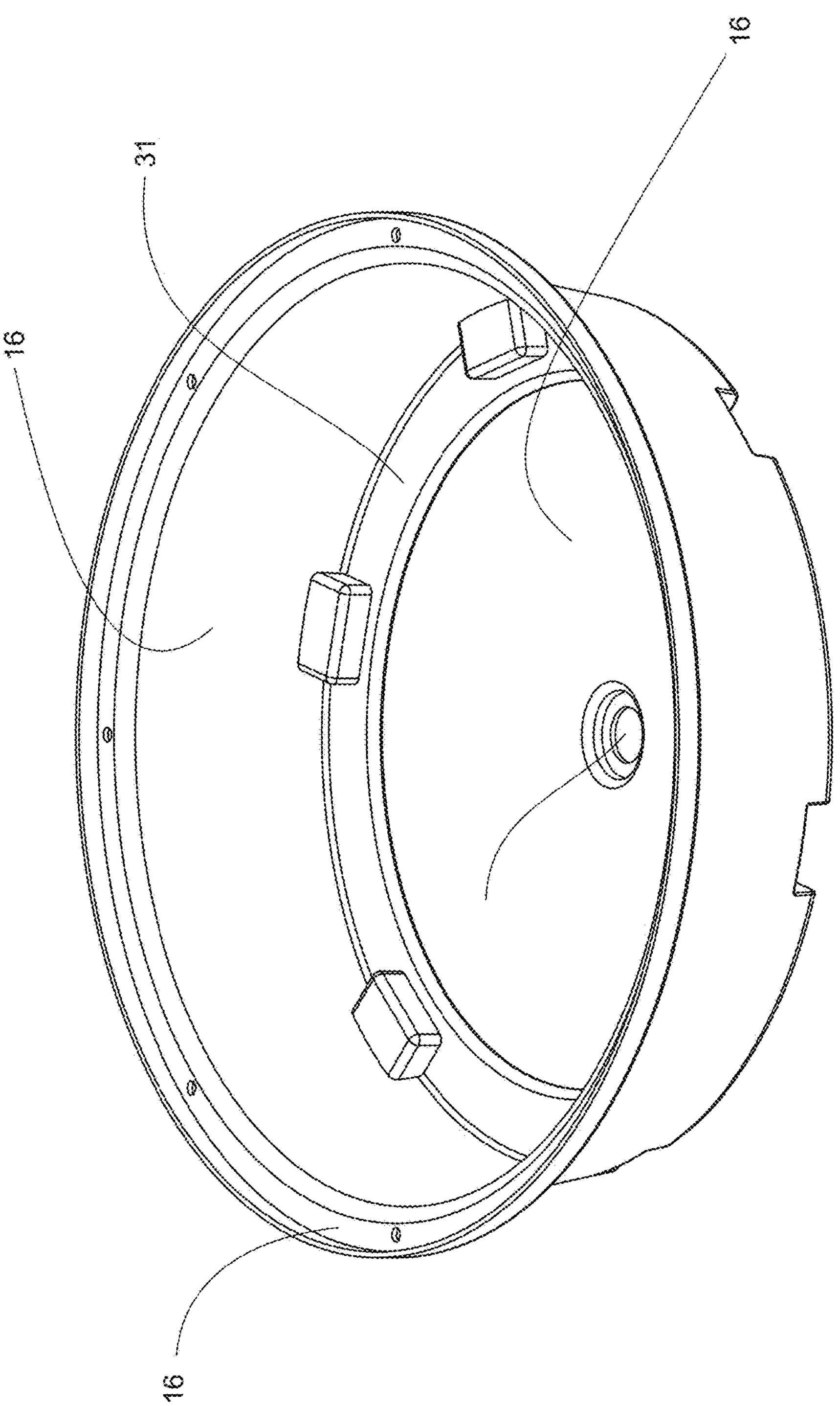


Fig. 6

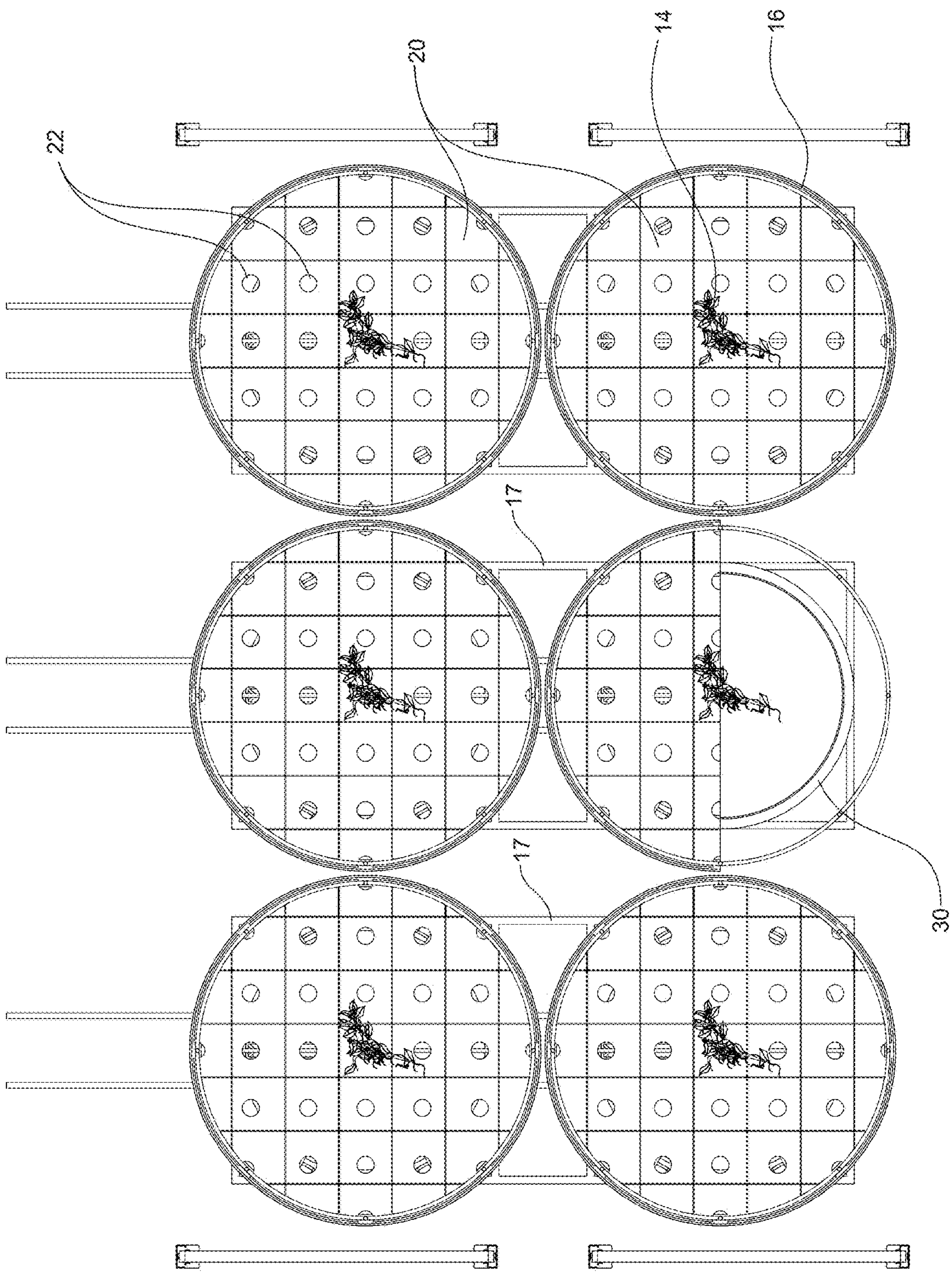


Fig. 7A

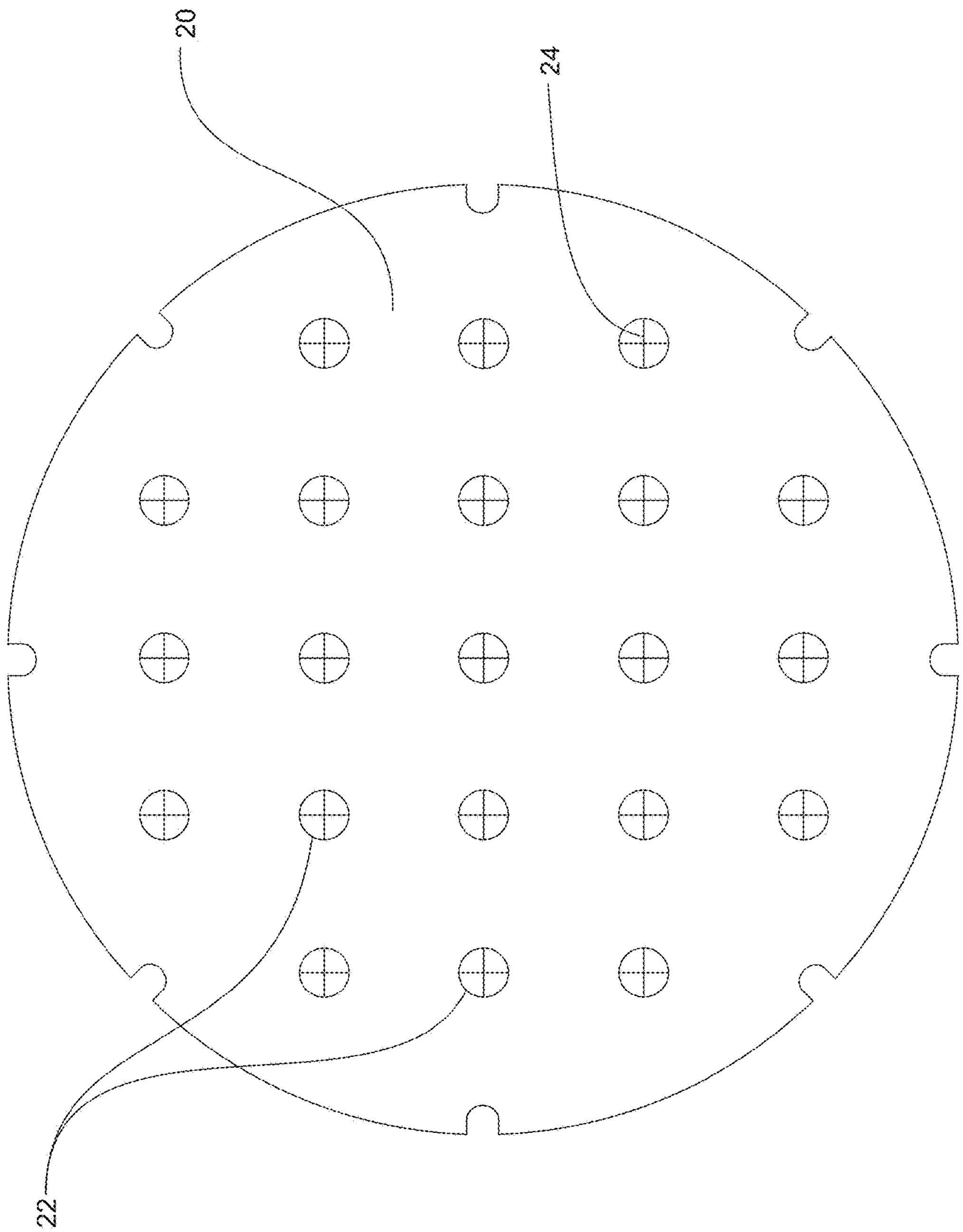


Fig. 7B

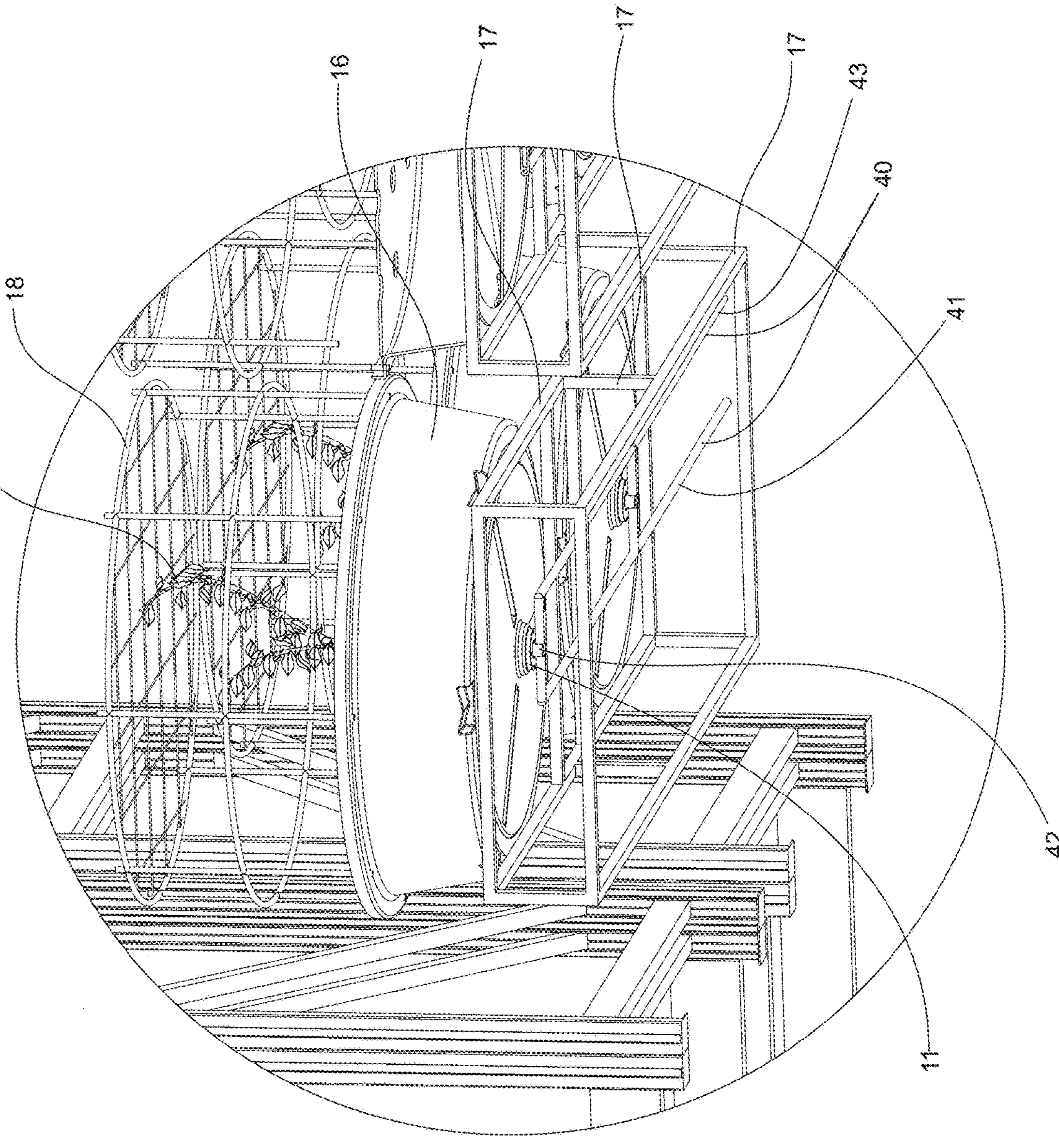


Fig. 8

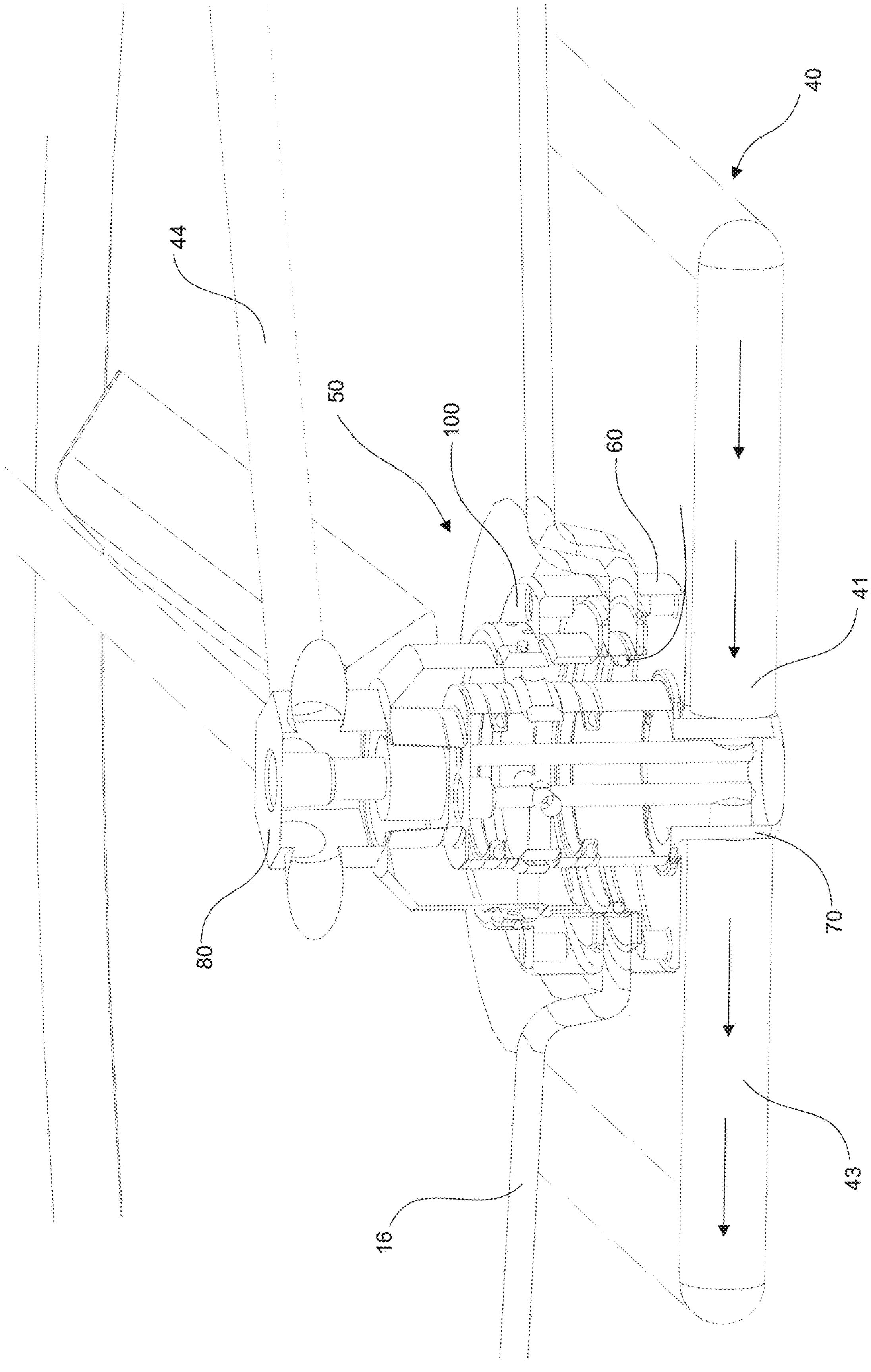


Fig. 9

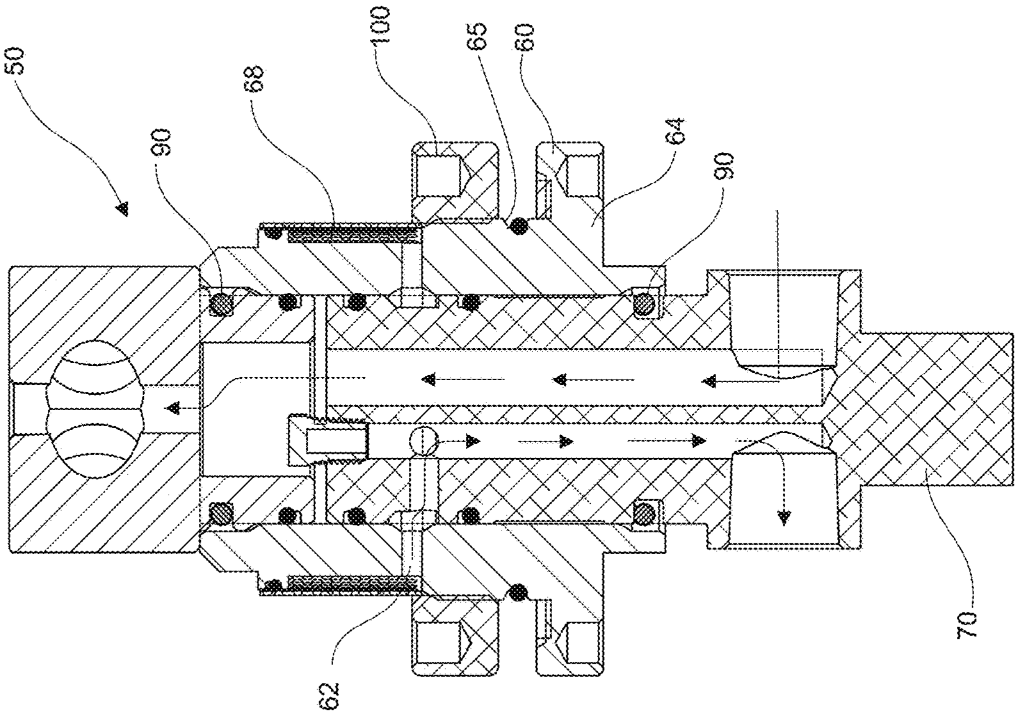


Fig. 10B

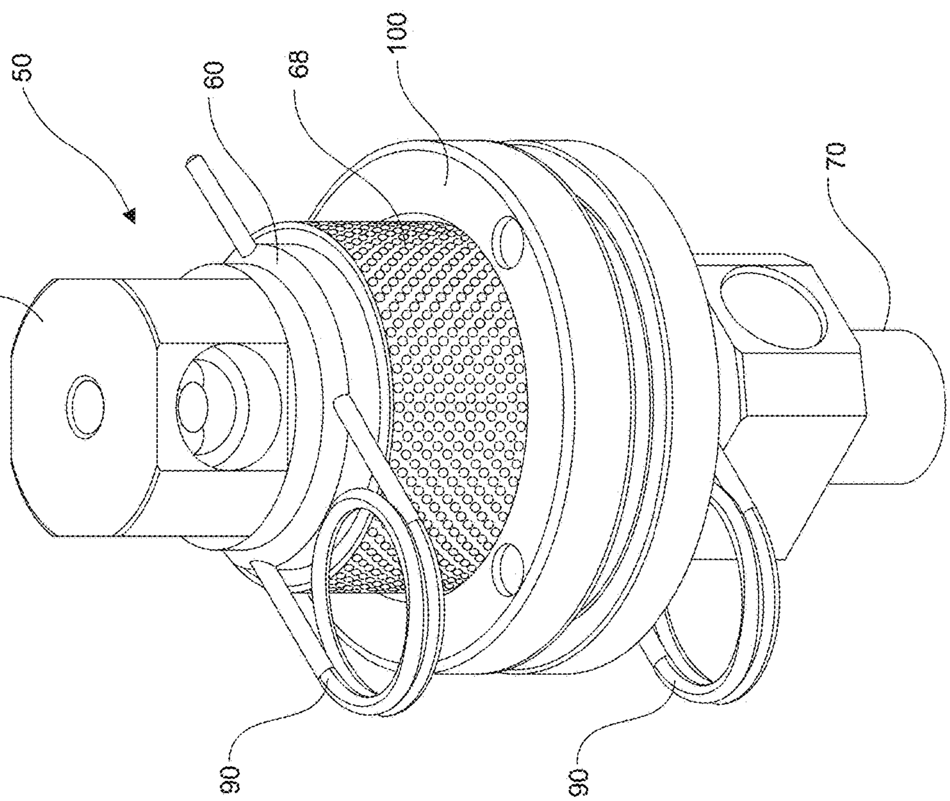


Fig. 10A

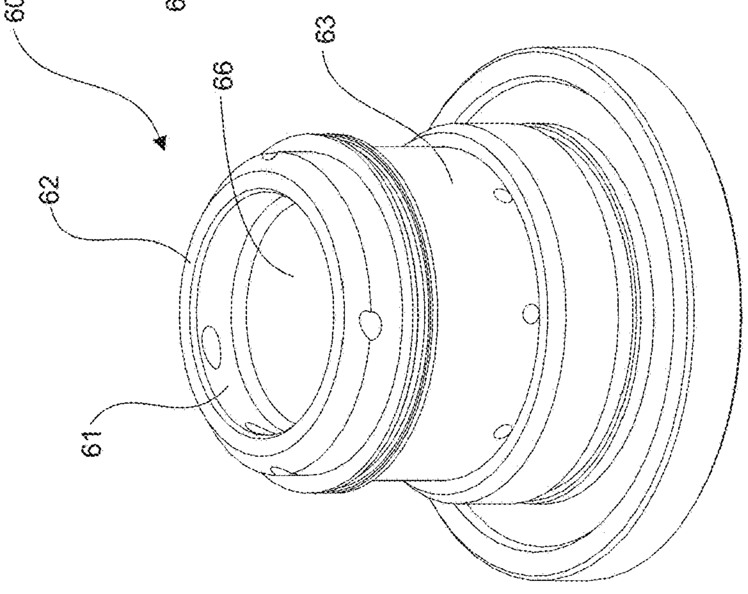


Fig. 11A

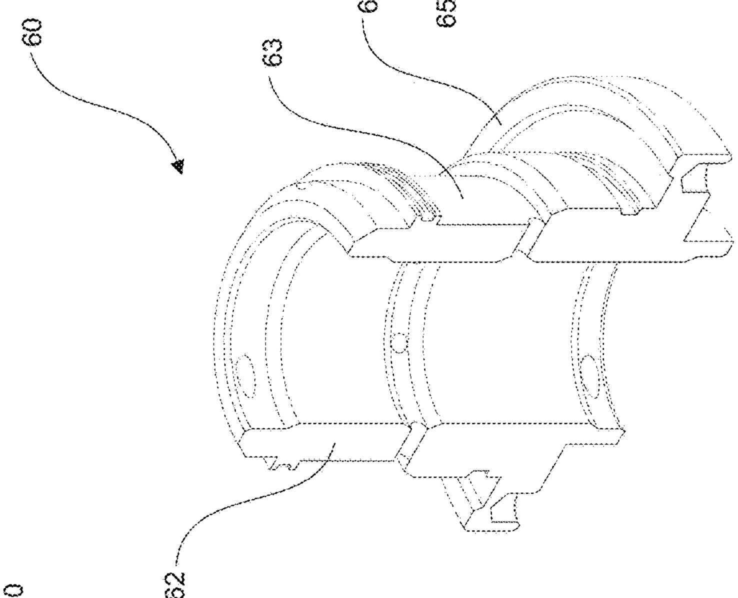


Fig. 11B

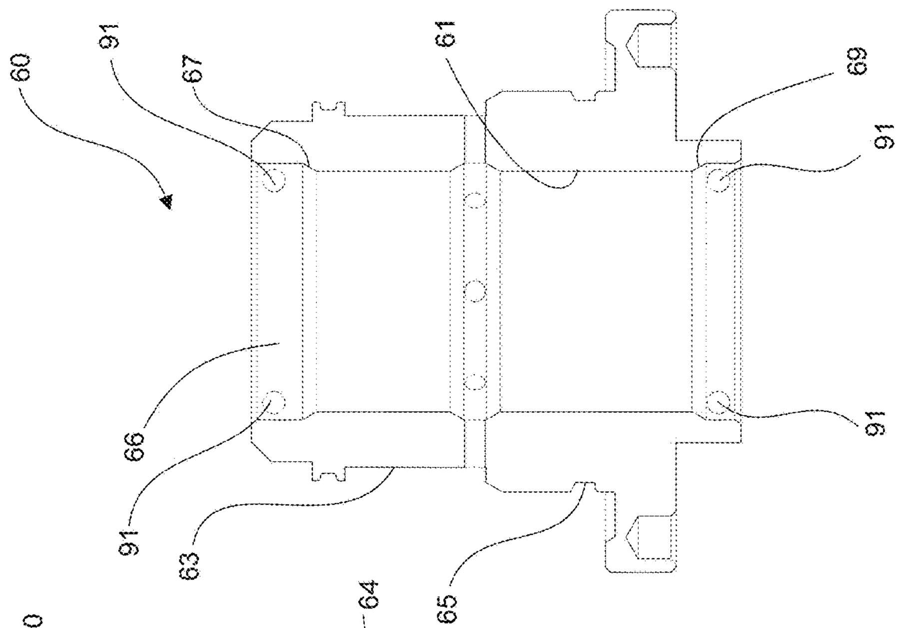


Fig. 11C

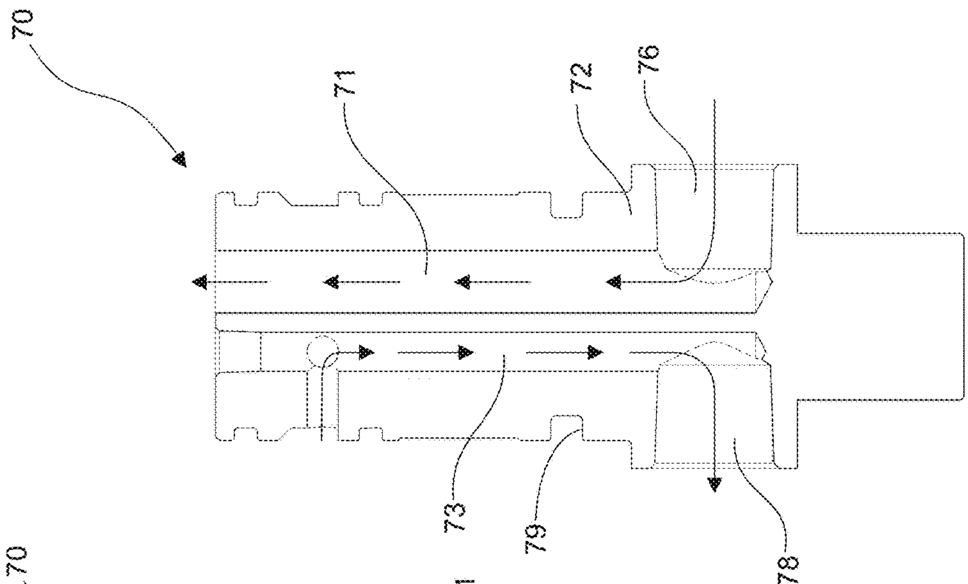


Fig. 12C

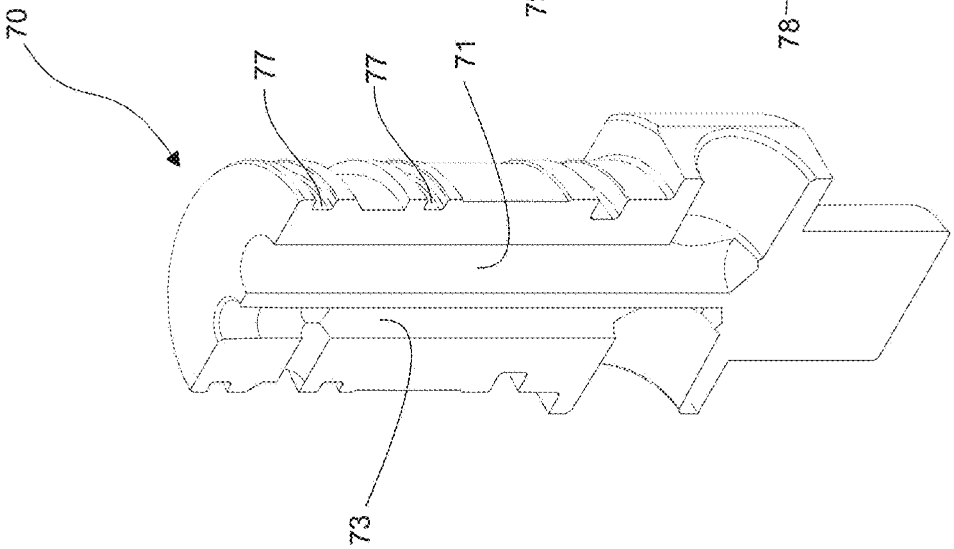


Fig. 12B

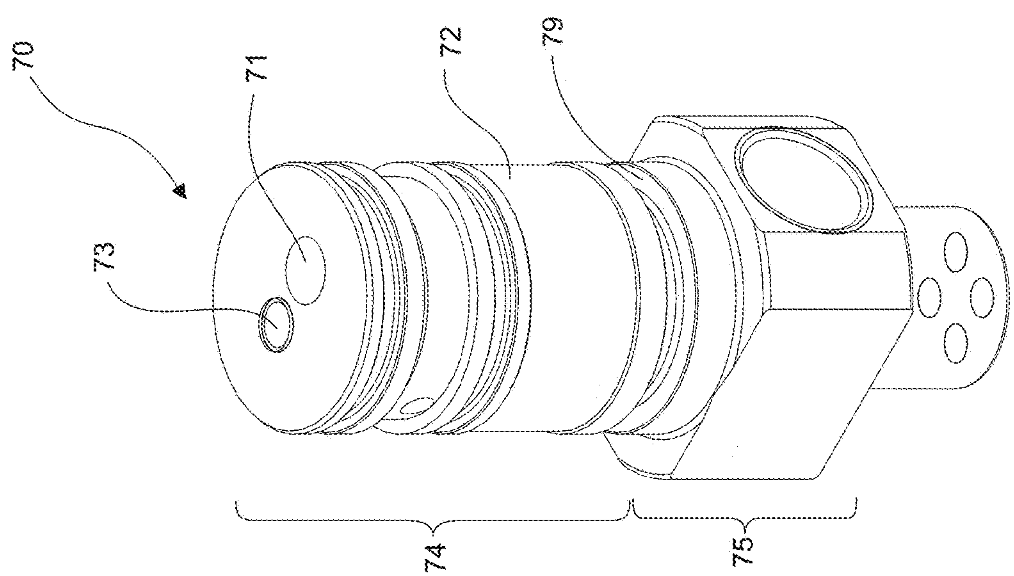


Fig. 12A

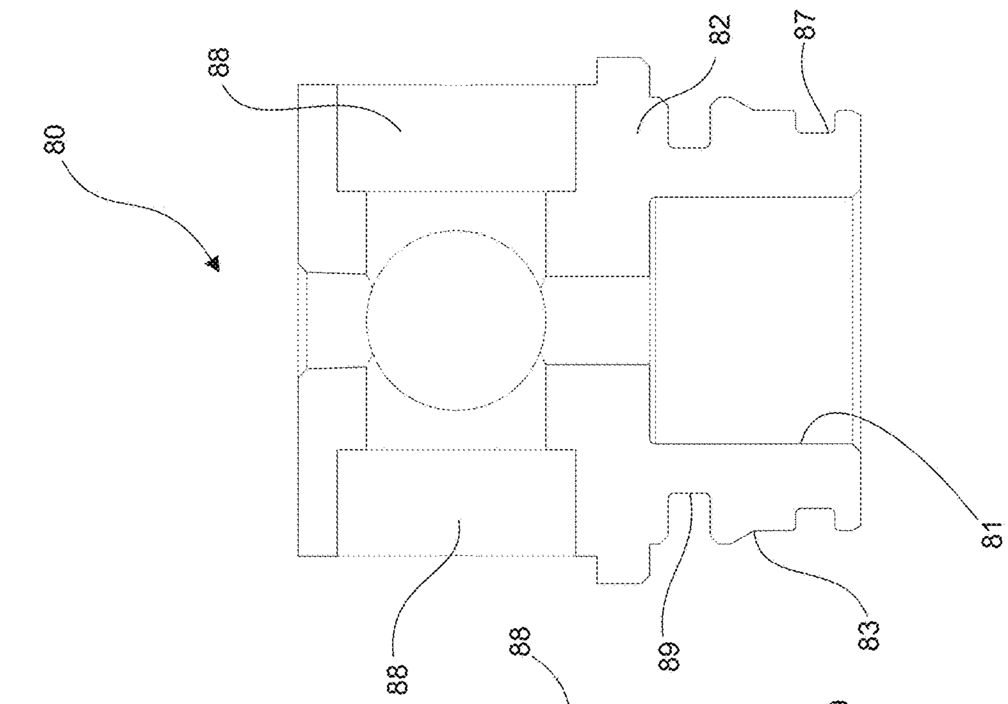


Fig. 13C

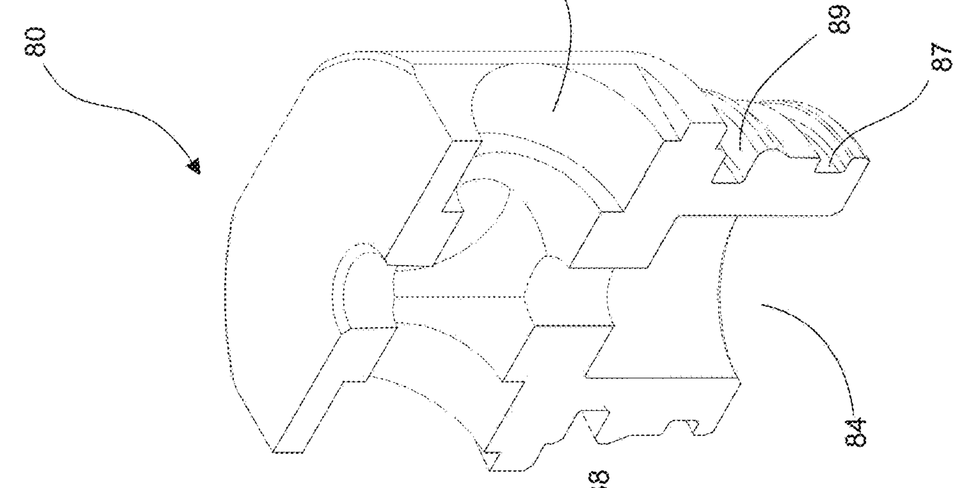


Fig. 13B

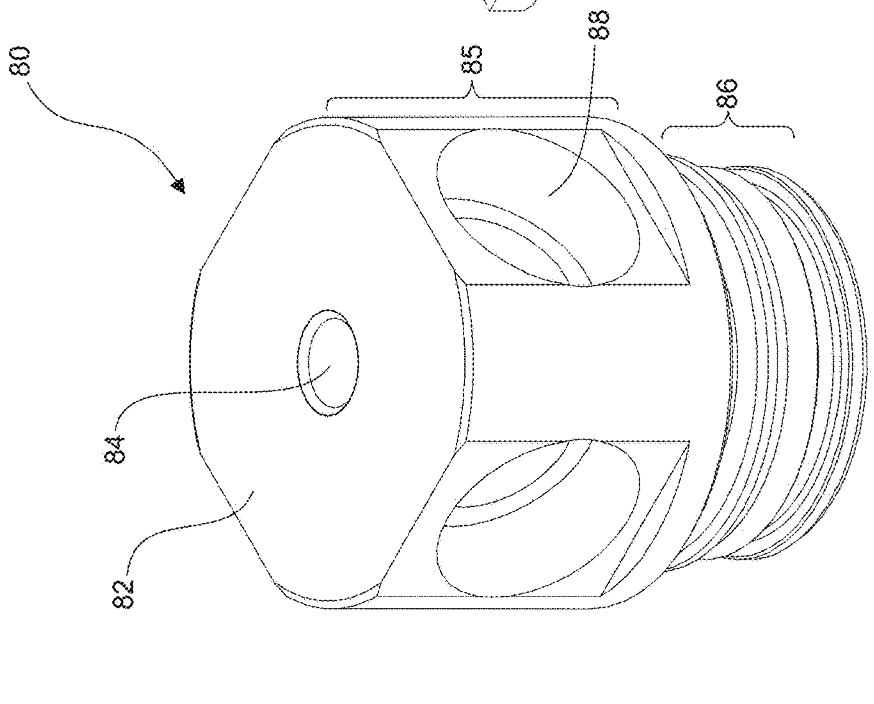


Fig. 13A

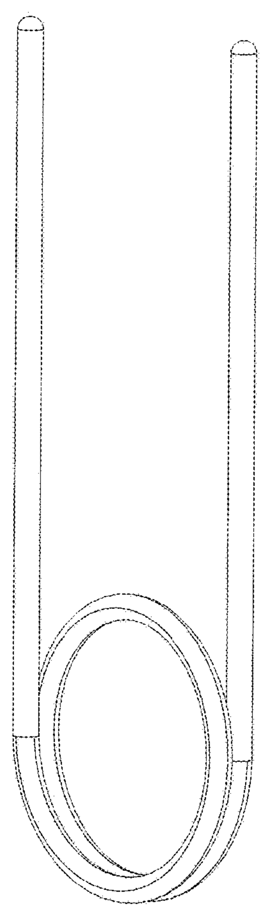


Fig. 14A

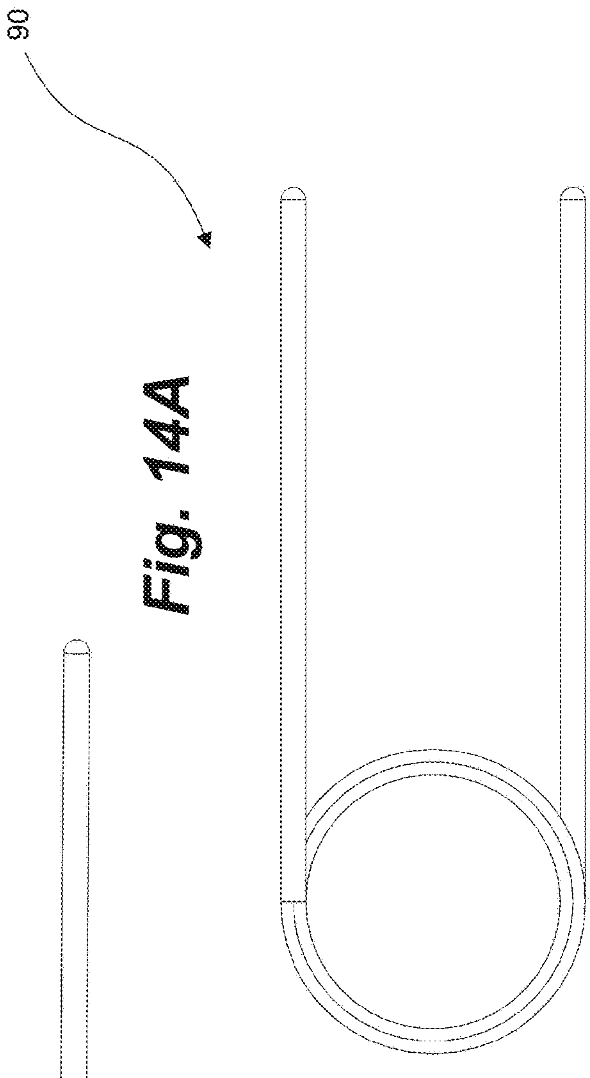


Fig. 14B

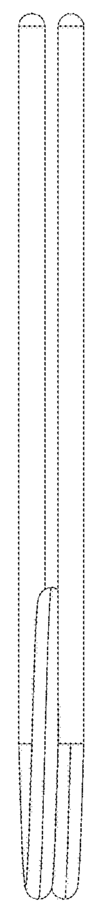


Fig. 14C

IO Tagnames will be structured as follows: prefix, resource and loop number. Sequential characters will be structured as follows: 1,2,3,4,5,6,7,8,9,A,B,C, ... X,Y,Z.

For example: Tagname: B1R1G1C12-TT001
Building #1, Row #1, Group #1, Process Growing Chamber Level 1 Position 2, Temperature Transmitter, Loop #001

Facility/Building/Area	
B1	Building #1
B2	Building #2
BX	Building #X (Where X is the sequential character)
Row	
R1	Row #1
R2	Row #2
RX	Row #X (Where X is a sequential character)
Group	
G1	Group #1
G2	Group #2
GX	Group #X (Where X is a sequential character)
Process ~ Level/Position	
N11	Nutrient Center, Level 1, Position 1
N21	Nutrient Center, Level 2, Position 1
NXX	Nutrient Chamber (Where X's are the sequential characters)
C11	Growing Chamber, Level 1, Position 1
C21	Growing Chamber, Level 2, Position 1
CXX	Growing Chamber (Where X's are the sequential characters)

41	42	43	44	45
31	32	33	34	35
21	22	23	24	25
11	12	13	14	15

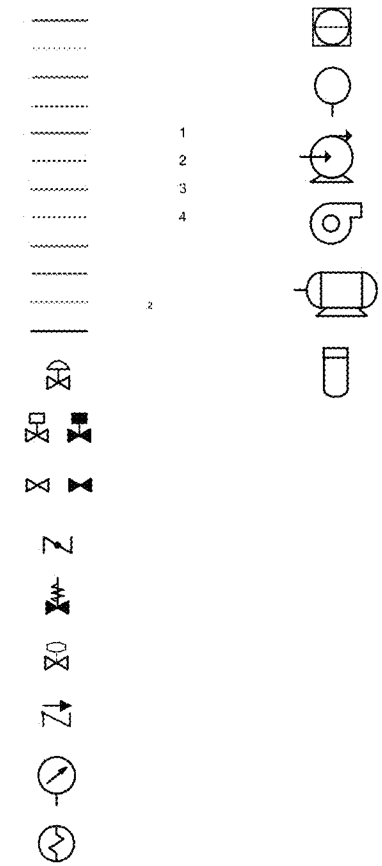


Fig. 15

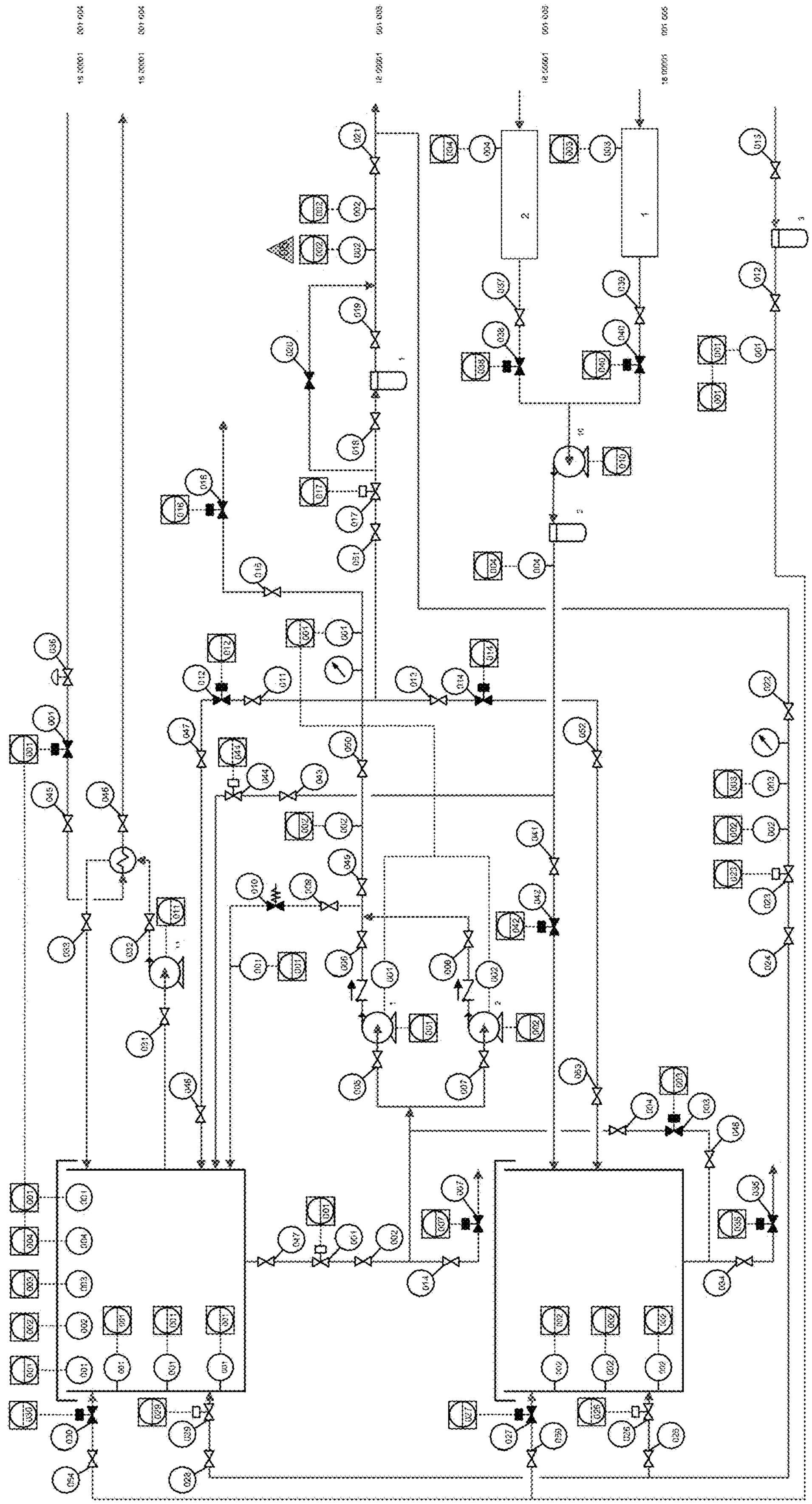


Fig. 16

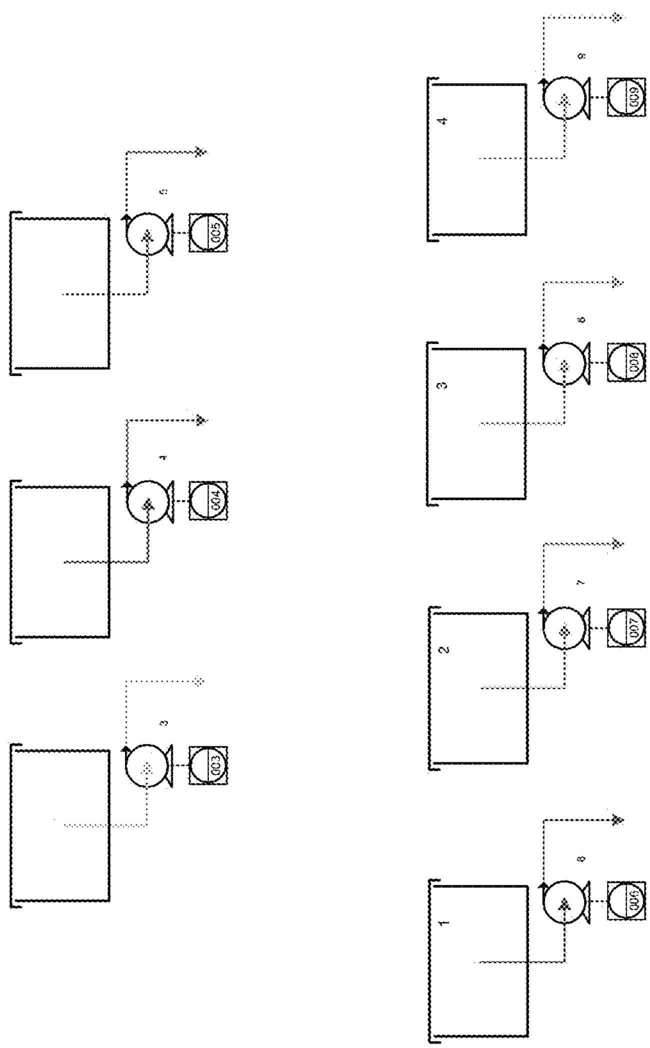


Fig. 17

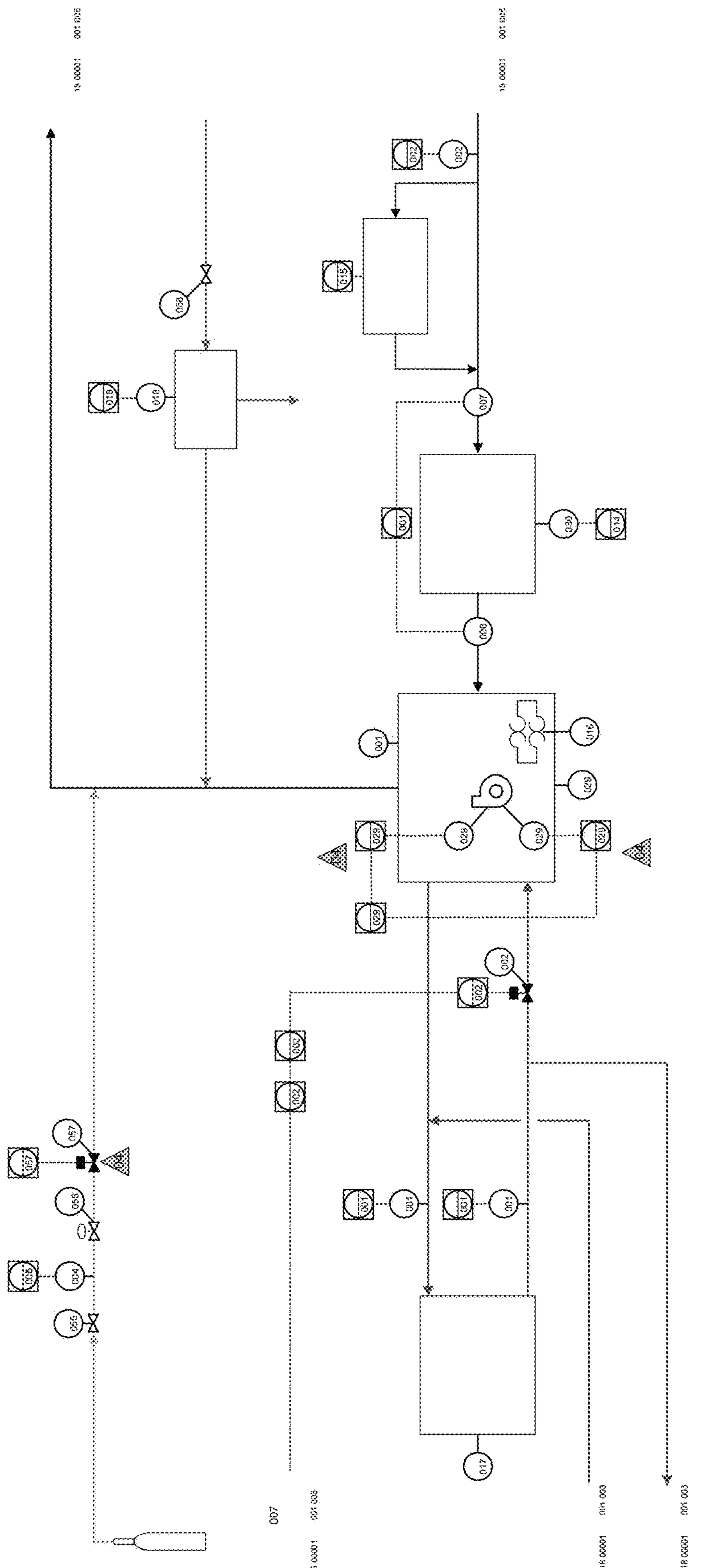


Fig. 18

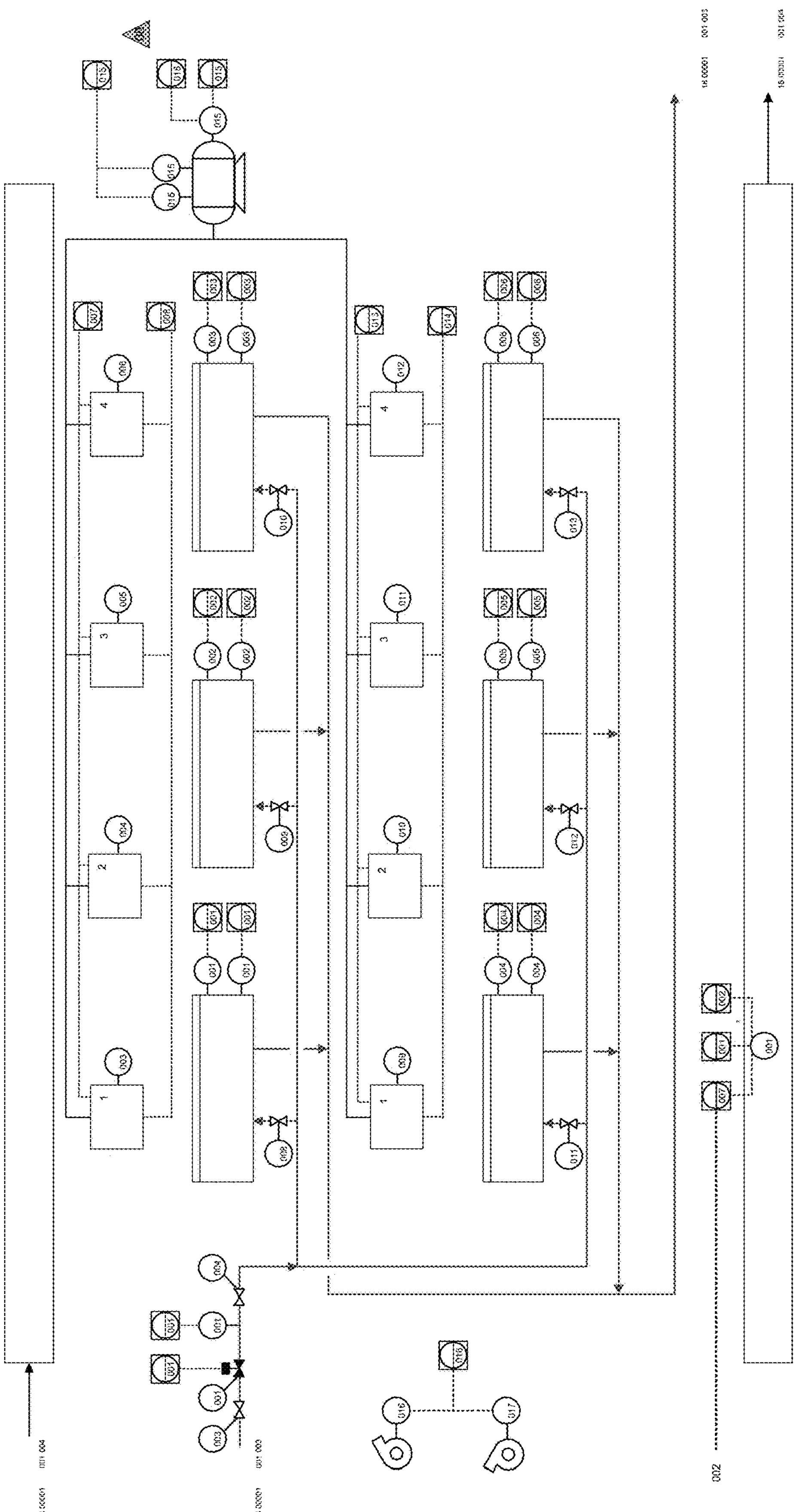


Fig. 19

AEROPONIC PLANT GROWING SYSTEM AND METHODS OF USE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefit of the filing date of U.S. Provisional Patent Application No. 62/675,254, entitled "AEROPONICS SYSTEM AND METHODS OF USE," and filed on May 23, 2018, the entire contents of which is incorporated herein by reference as if set forth in full.

FIELD

[0002] Apparatus and methodologies are provided for improved aeroponic plant growing. More specifically, improved aeroponic plant growing systems and methods of use are provided, wherein the plants may be marijuana plants.

BACKGROUND

[0003] Aeroponics is the process of growing plants without the use of soil or an aggregate medium. Aeroponics systems traditionally involve suspending the plants in a closed or semi-closed environment and then spraying the plant's roots with an air or mist of nutrient-rich water solution. The oxygen-rich environment created within aeroponic systems enables plants to absorb more nutrients while using less water than conventional growing methods, increasing crop maturation rates and yields. As a result, harvests from aeroponic growing systems are significantly larger than soil-grown plants (e.g. as much as 10 times larger).

[0004] Conventional aeroponic systems comprise an enclosed grow chamber separated into two main portions: a first upper portion configured to house the plant canopy, referred to as the "canopy zone"; and a second lower portion configured to house the root portion of the plant, referred to as the "root zone". The two zones are physically separated, such as by a foam disc wrapped around the stem of the plant, such that the roots of the plant may be sprayed with the nutrient-rich solution. Due to the roots being exposed to the environment, aeroponics systems must be carefully monitored and maintained in order to maximize nutrient availability to the roots, and disruptions to the environment should be avoided in order avoid contamination of the system.

[0005] The highly-controlled nature of aeroponic plant growing processes makes them an ideal system for growing government-regulated plants, such as marijuana (marihuana), where strict parameters surrounding the production of the plant are imposed and enforced by health and safety organizations (e.g. Health Canada). For example, where the marijuana is grown for medical purposes (or even recreational use, where legal), government agencies impose restrictions on the odour or pollen that can be emitted from growth chambers, and the final plant product must pass strict lab testing to ensure that inorganics, such as pesticides or heavy metals, are not present. Moreover, organics such as mold spores, mildew, and bacteria etc. must also not be present. Due to the strict growing requirements, systems where the plants are protected from exposure to sources of contamination in the air or water are desirable. Moreover, systems that provide increased crop maturation rates and yields without the use of pesticides or other chemical additives are also desirable.

[0006] On the other hand, the delicate growing environment of aeroponics systems can make them difficult to use successfully, particularly on a large scale. Without soil or other growth medium as a buffer, plant roots can quickly dry out and die when the environment becomes disrupted, for example, where air quality, temperature, pressure or humidity are altered, nutrient-mist composition is poorly applied where pumps or misters become clogged, or where human intervention disturbs the plants, etc. However, many plants, including marijuana plants, benefit from regular pruning of lower portions of the plant canopy (e.g. where light is restricted, causing underbalanced distribution of nutrients), resulting in regular "disruption" to the aeroponic environment. Although regular pruning can increase both the density and yield of the plants, it must be performed in a manner that minimizes disturbance of the growth chamber environment and the surrounding plants. Moreover, parameters within aeroponics systems must be closely measured and controlled order to ensure desired levels are maintained within the system.

[0007] There is a need for an improved aeroponic plant growing system that can be used with minimal interruption to the growth chamber and the plants housed therewithin. It is desirable that the system be a closed-loop automated (or semi-automated) system where the upper and lower portions of the growth chamber can be monitored and controlled independently, and minimizing the likelihood of contaminants (e.g. mold or mildew) and enabling stringent control over the emission of odour and pollen. It is also desirable that the system provide an expansive growing area, i.e. to maximize volume within the growth chamber, and where the growing area is rotatable for enhanced nutrient supply and drainage. Finally, it is desirable that the system provide easy access to the plants for inspection, pruning, and harvesting, while maximizing the growth space within the growth chamber.

[0008] There is a further need for an improved aeroponic plant growing system, such as an aeroponics system, that can be used to grow a large number of plants without significantly increasing the resources, the environmental impact, the complexity or overall footprint of the system. It is desirable that the system be as compact and space efficient as possible, requiring minimal human interaction to grow the crop, and allowing easy harvesting of plants or cleaning and maintenance of the system. It would be advantageous for such an improved system to be equipped with sensors for monitoring and managing growth processes, and to alert or alarm the grower where troubleshooting is needed or problems arise.

SUMMARY

[0009] According to embodiments, improved apparatus and methodologies for aeroponically growing a large crop of plants are provided. More specifically, an aeroponic plant growing apparatus is provided comprising at least one climate-controlled growth chamber containing a plurality of plant support structures for receiving and supporting a plurality of plants in close proximity to one another. Each plant support structure may be independently rotatable about a central axis, and may contain a divider for separating the plant support structure into an upper zone for supporting a canopy portion of the plant, and a lower zone for supporting a root portion of the plant. Each plant support structure may also contain at least one valve for establishing fluid connection with a nutrient solution delivery system, such that the plant support structures may be rotated without interrupting delivery of a nutrient-rich solution to the plants. The at least one valve further provides that each plant support structure can be quickly and easily removed from the growth chamber, via a quick-release mechanism, where desired.

[0010] In some embodiments, the system may comprise a closed-loop apparatus, wherein each at least one climate-controlled growth chambers may be enveloped by a material forming a ‘wall’, such material comprising a non-porous, light-reflective material. The at least one growth chambers may be configured to maximize the overall growing area, and may be stacked one upon another, with each chamber still being monitored and controlled by a single controller, processor, or control system.

[0011] In some embodiments, the system may further comprise a nutrient delivery system (or irrigation system) in fluid communication with each plant support structure within the growth chamber. The nutrient delivery system may be configured to deliver a nutrient-rich solution to the lower zone of each plant support structure, and to retrieve excess solution draining therefrom (i.e. solution that is not absorbed by the root portion of the plants within the lower zone). Retrieval of un-used nutrient solution may be retrieved within the closed-loop system, providing controlled recirculation of the solution, reducing losses, and eliminating the risk of contamination of the solution.

[0012] In some embodiments, the system may further comprise a plurality of sensors for measuring the closed-loop environment within each growth chamber, and to generate a signal indicative thereof. Such sensors may include, without limitation, temperature, pressure, humidity, CO_2, etc. of the air, the fluids, or a combination thereof within the systems. The system may further comprise a single controller, processor, or control system for receiving the signals from the sensors, the single controller, processor, or control system being programmed to control the climate within each at least one growth chamber.

[0013] In some embodiments, each of the plurality of plant support structures may further comprise at least one valve (e.g., a rotating coupler) sealably positioned within the plant support structure for establishing fluid communication between the nutrient delivery system and at least one fluid manifold for delivering the fluid to the root zone of the plants. Advantageously, the at least one valve provides means for rotating each plant support structure independently about its central axis, while the plant support structure remains connected to the closed-loop nutrient delivery system. As such, each individual plant support structure may be rotatable without being disconnected from the growth chamber, and without interruption to the nutrient delivery system cycling fluids into and out of each plant support structure.

[0014] In some embodiments, the at least one valve comprises a housing for releasably connecting a stationary coupler shaft with a rotatable manifold (nozzle) mount. The releasable connection between the housing and the shaft may comprise a first quick-release mechanism, while the releasable connection between the housing and the mount may comprise a second quick-release mechanism. In some embodiments, first and second quick release mechanisms may comprise a lock-spring.

[0015] According to embodiments, methods of growing plants aeroponically are provided, the methods comprising providing a plurality of rotatable plant support structures releasably positioned within at least one climate-controlled plant growth chamber, each plant support structure having a divider for dividing the structure into an upper zone for supporting a canopy, and a lower zone for supporting a root portion of the plants, and planting a plurality of plants within the plant support structures.

[0016] In some embodiments, the method further comprises providing a closed-loop nutrient-rich solution to the root portion of the plants in the lower zone, and retrieving excess solution draining therefrom. The method may further comprise providing a plurality of sensors for measuring the climate within each plant support structure and generating signals indicative thereof, providing a controller for receiving the signals from the sensor and, based on the signals received from the sensors, controlling the climate within each growth chamber. Methods further comprise planting a plurality of plants within each plan support structure and supplying the root portion of the plants with a nutrient-rich solution (via a closed-loop fluid system) and, where desired, rotating one or more plant support structures to access the plurality of plants.

[0017] In some embodiments, the method further comprises providing at least one valve sealably positioned within each plant support structure, the valve comprising at least one quick-release mechanism for removal of some or all of the plant support structure from the growth chamber. The at least one quick-release mechanism may comprise a first lock-spring for removing a manifold from the plant support structures, and a second lock-spring for removing the plant support structures from the growth chamber.

BRIEF DESCRIPTION OF THE FIGURES

[0018] FIG. **1** is a perspective view of the present aeroponics system according to embodiments herein, the system having at least six plant support structures within one growth chamber. It should be appreciated that the present system comprises growing the plants within an enclosed or enveloped chamber, such that the climate-controlled chamber creates a closed-loop environment;

[0019] FIG. **2** is a side view of the aeroponics system shown in FIG. **1**;

[0020] FIG. **3** is a zoomed in perspective view of the present aeroponics system according to embodiments herein;

[0021] FIG. **4** is a cross-section of the perspective view in FIG. **3**, wherein the front three plant support structures within the growth chamber are removed for illustrative purposes;

[0022] FIG. **5** is a zoomed in view of the present aeroponics system according to embodiments herein;

[0023] FIG. **6** is a perspective view of a rotatable plant support structure, according to embodiments herein;

[0024] FIG. **7**A is a top down view of the present rotatable plant support structures, according to embodiments herein;

[0025] FIG. **7**B is a top down view of a divider for positioning into a plant support structure, according to embodiments herein;

[0026] FIG. **8** is a zoomed in perspective view of the underside of a plant support structure, according to embodiments herein;

[0027] FIG. **9** is a zoomed in perspective view of a rotating coupler positioned within the drain hole of a plant support structure, according to embodiments herein;

[0028] FIG. **10**A is an isolated perspective view of the coupler shown in FIG. **9**, and FIG. **10**B provides a cross-sectional side view of the coupler, according to embodiments herein;

[0029] FIGS. **11**A, **11**B, and **11**C show different views of the rotating coupler housing in isolation, according to embodiments, where FIG. **11**A shows a perspective view of the housing, FIG. **11**B shows a cross-section perspective view, and FIG. **11**C shows a cross-section side view;

[0030] FIGS. **12**A, **12**B, and **12**C show different views of the rotating coupler shaft in isolation, according to embodiments, where FIG. **12**A shows a perspective view of the shaft, FIG. **12**B shows a cross-section perspective view, and FIG. **12**C shows a cross-section side view;

[0031] FIGS. **13**A, **13**B, and **13**C show different views of the spray nozzle mount in isolation, according to embodiments, where FIG. **13**A shows a perspective view of the mount, FIG. **13**B shows a cross-section perspective view, and FIG. **13**C shows a cross section side view;

[0032] FIG. **14** shows different view of the lock-spring in isolation, according to embodiments, where FIG. **14**A shows a perspective view of the lock-spring, FIG. **14**B shows a top view, and FIG. **14**C shows a side view;

[0033] FIG. **15** shows a list of symbols and standard naming convention used for FIGS. **16-19**, and also includes a representation of the present system having an example of up to twenty growth chambers according to embodiments, wherein the representation includes, for example, a nutrient center and nineteen elevated or 'stacked' growth chambers (names are given to each chamber based on function and location, e.g., C41 denotes a growth chamber in the first column of level 4);

[0034] FIG. **16** shows a representation of the nutrient delivery system (i.e. the nutrient center), the system having a plurality of fluid tanks, the componentry for feeding and draining fluids to/from the tanks, and showing how the system is used so as to pump filtered nutrient rich solution to the growth chambers;

[0035] FIG. **17** shows a dosing system according to embodiments including, for example, storage containers and pumps for controlling pH and nutrient levels (up to four), and dispensing of a hydrogen peroxide mixture to the fluid tanks of the nutrient deliver system;

[0036] FIG. **18** shows a representation of the present air treatment system according to embodiments, the system including for example CO_2 enrichment, sanitizing, temperature and humidity control; and

[0037] FIG. **19** shows a representation of a growth chamber including for example air, light and nutrient solution control, and monitoring instrumentation.

DETAILED DESCRIPTION

[0038] Although several embodiments, examples, and illustrations are disclosed below, it will be understood by those of ordinary skill in the art that the invention described herein extends beyond the specifically disclosed embodiments, examples, and illustrations and includes other uses of the invention and obvious modifications and equivalents thereof. Embodiments of the invention are described with reference to the accompanying figures, wherein like numerals refer to like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any limited or restrictive manner simply because it is being used in conjunction with a detailed description of certain specific embodiments of the invention. In addition, embodiments of the invention can comprise several novel features and no single feature is solely responsible for its desirable attributes or is essential to practising the inventions herein disclosed.

[0039] Embodiments herein relate to improved aeroponics systems and methods of use, and specifically to improved aeroponics systems and methods for the controlled cultivation of a plurality of plants, such as marijuana plants. It is known that aeroponics systems for growing plants must be closely monitored and tightly controlled to optimize growing conditions, particularly where the plants being cultivated are marijuana plants, or the like. The present system aims to provide an improved aeroponics system having maximized grow space for cultivating a large crop of plants within the system, while providing a closed-loop system to minimize exposure of the plants to contamination and human interaction.

[0040] By way of background information, U.S. Patent Application Pub. No. 2017/0223912 (the '912 Application) provides a detailed description of conventional aeroponics systems that are used for growing plants, such as marijuana plants. As follows, a general outline of known aeroponics apparatus and methodologies are is provided, the outline being reproduced generally from '912 Application to establish the basic principles of aeroponics systems, and then embodiments of the presently improved aeroponic apparatus and methods of use are introduced.

[0041] Aeroponics Plant Growing Systems Generally

[0042] As outlined in the '912 Application, methods, apparatus and systems for aeroponically growing plants, such as marijuana plants, involve various subsystems that interact in feedback loops to provide the tightly-monitored and controlled growing environment, whereby exposure of the plants to sources of contamination (e.g. pesticides, mold, mildew) in the air or water are minimized, and whereby plant yield is maximized. Control of such subsystems may be automated, with feedback signals from various sensors monitoring the environment. The systems are often configured to minimize human interaction with the growing environment. For example, problem detection may be mitigated by automatic adjustment of operational parameters and alerts provided to an operator permitting the operator to intervene manually where required.

[0043] Growth Chamber:

[0044] The environment required for aeroponic plant growth is known to be contained within a physical structure, referred to as a 'growth chamber', which is specifically designed for planting and irrigating the plants. The chamber itself comprises means for supporting the plants, such plant support means configured to permit exposure of the roots of the plant to air in the climate controlled "root zone" and permitting a nutrient-rich solution to be sprayed on the roots via an irrigation system. The walls of the growth chamber may be configured to envelope the structure containing the plants; provided that air flow into the chamber and past the plants is permitted. The walls may comprise any suitable material for maintaining an aeroponic environment, such as a non-porous light-reflective material. Generally, the growth chamber may further comprise one or more access panels for service and maintenance of the structures inside the chamber.

[0045] Lights:

[0046] Artificial lighting may be evenly dispersed about the chamber to illuminate the plants. Lighting systems used for the aeroponic growth of plants must be closely monitored and controlled. Known systems are increasingly using horticultural appropriate smart LED lighting systems (e.g., Raging Kush®, SCYNCELED, USA). Such systems, which may be specifically designed for large growing operations, can be suitable for controlling light intensity and scheduling (e.g., day/night cycles), for addressing high humidity, and for use in frequently cleaned environments. Ideally, such lighting systems may serve to maximize lighting within limited space. At least one sensor may be positioned within the growth chamber for monitoring lighting systems, such sensor being used alone or in conjunction with temperature (and other) sensors as described in more detail herein.

[0047] Temperature, Pressure, Humidity:

[0048] Temperature, pressure, and humidity within the growth chamber used for aeroponic plant growth must be closely monitored and controlled. Air temperature and humidity sensors may be used to monitor temperature and humidity levels and gradients within the growth chamber. In some embodiments, signals received from the sensors can be used to prompt a controller to operate air moving device(s) and HVAC in order to maintain the temperature and humidity levels and gradients within the chamber. In other embodiments, signals received from the sensors can be used trigger an alert to an operator, for example, where the conditions within the chamber cannot be adapted or the environmental controls cannot be maintained by the controller alone. As would be understood, temperature and humidity sensors may be independent sensors, may be integrated into one sensor, or may be a combination thereof

[0049] Barometric Pressure:

[0050] In addition to temperature and humidity, barometric pressure within the aeroponic growth chamber may be closely monitored and controlled. In some embodiments, barometric sensors may be provided, such sensors operative to measure the pressure in the air or other fluid at the sensor.

[0051] Air Flow:

[0052] Air flow within the growth chamber should be closely monitored and controlled. Known aeroponic systems advantageously allow for the customization of air flow within the chamber in order to cause plant swaying and motion, thereby reducing dead air pockets and stimulating the plants to produce more fibrous stalks. As a result, the plants become more durable to handle, they can support a heavy crop, and less prone to wilting if undesirable conditions accidentally arise.

[0053] Aeroponic growth chambers can comprise cooling and ventilation (HVAC) systems including, for example, one or more air moving devices (e.g., fans, blowers, etc.), air conduits (e.g., tubes, ducts, etc.), air conditioners, and air filters (e.g., carbon filters, HEPA filters, etc.). It is an advantage that the cooling and ventilation system may operate mainly on recirculated air for efficiency and to minimize the amount of air being filtered at the inlet and outlet to the environment where contamination could enter or leave the growth chamber. In some embodiments, one or more exhaust air sensors can be positioned proximate an exhaust outlet of the growth chamber to monitor concentrations of contaminants in air exhausting from the chamber, and to compare such contaminant concentrations with background levels outside the growth chamber (or predetermined and desired baseline levels within the chamber). If desired, the proportions of recirculated and new air may be adjusted automatically by variable speed air movers.

[0054] Feedback Control/System Automation:

[0055] Measurement of the above-referenced and various other parameters within aeroponic growth chambers facilitate feedback loops to a controller, thereby establishing automatic (or semi-automatic) control of the environment, and enabling optimization of the growing conditions for the plants and operational functions of the growth chamber. It is an advantage of aeroponic plant growing systems that measurements acquired by various sensors can be sent as signals to a controller, which then responds to the signals in a manner consistent with programming of the controller. For example, based upon signals received from the sensors, variables within the chamber can be modified including, without limitation, the "day/night" light cycle timing, temperature and humidity levels, air flow rates and oxygenation levels, timing and duration of nutrient delivery, concentration of nutrients and/or pH levels within the solution (i.e. tailoring the solution, via the dosing regimen to optimize development of the specific plants), sanitation cycles to clean and maintain the growth chamber, etc. Aeroponic growing systems operated in this manner are therefore not only able to accurately monitor the growth chamber environment based upon actual parameter values received from the sensors, but are also able to take any action as may be necessary to adjust the environment to optimal growing conditions. By way of example, when adjusting the pH, the nutrient-rich solution may be mixed and continuously sampled with a pH sensor to determine whether the action taken had the desired result. Or that varying the speed of a fan to change the airflow adjacent the plants, barometric pressure may be determined within the growth chamber in order to ensure that the intended air flow changes actually occur.

[0056] Nutrient Delivery or "Irrigation" System:

[0057] Aeroponic growing systems operate on the ability to provide a nutrient-rich water solution to the roots of the plants. As such, aeroponic systems require a nutrient delivery system, also referred to as an "irrigation" system. Specifically, growth chambers can be separated into a "root zone", a "stalk zone" for supporting the stalk of the plants, and an upper "canopy" zone. Nutrient delivery systems can comprise one or more pumps fed from one or more nutrient tanks (e.g. a dosing system), with fluids first passing through at least one filters (e.g., particle filters). The one or more pumps often pump the nutrient-rich solution to at least one solution delivery header in or proximate to the growth chamber. A pressure monitoring sensor, located proximate to a furthest point in the delivery header, may provide feedback to the controller to control the one or more pumps to adjust the pressure to a desired level in order to compensate for solution losses in conduits and a variable number of growth chambers, which may be irrigated at any given time.

[0058] The delivery header may be in fluid communication with the growth chamber via one or more valves. Opening and closing of the one or more valves may follow timing patterns set by the controller and may vary depending upon the growth phase of the plants, or other such factors as would be known to a person skilled in the art. The one or more valves may feed distributors that are in fluid communication with a plurality of sprayers (e.g., nozzles) within the root zone. Nutrient-rich solution may be provided to the sprayers at a sufficient pressure to create a mist in the root zones, thereby saturating the roots of the plant. A skilled person would know and understand that variations of the chemical components of the solution, or of the cycle timing that the solution is administered, may be made in order to optimize plant growth (and to control the root length/mass).

[0059] The nutrient-rich solution that is not absorbed by the plants may flow down to the bottom of the plant support structure, before draining from the growth chamber through one or more drains and, depending on the system, may be recycled or discarded. Sensors may be provided to measure and monitor fluid runoff rate and collected volume within the chamber. In some embodiments, at least one level probe may be provided, giving a digital indication of whether or not liquid is present at a predetermined measuring point, which might indicate that collected liquids have reached high-level limit (and that the introduction of more nutrient-solution should be decreased), or that a fluid-flow blockage has occurred in any one individual plant support structure. Signals received from the at least one level probe can be used to prompt the controller when a problem is detected and, where desired, to immediately stop whatever action is causing a rise in the liquid level. Where required, an alert may be provided to an operator permitting the operator to intervene manually. Information collected from individual sensors, or from a combination of a plurality of sensors can provide useful information to the controller and/or operator for use in logical decision making in combination with other input variable.

[0060] Nutrient Solution Dosing System:

[0061] Aeroponic growing systems typically comprise a nutrient-rich solution dosing system to ensure that fluids sprayed onto the roots optimize plant health and growth. Dosing systems can comprise one or more tanks for mixing and storing the solution. It would be understood that the number of tanks may depend upon the number of different kinds of chemical components, the chemical components being stored individually in separate storage containers. Typically, the nutrient-rich solution may be a water-based solution comprising other chemical components including, for example (and without limitation), nutrients, acid, alkali, trace elements, flavor additives, hydrogen peroxide, enzymes that facilitate plant processes for plant growth, sugars (e.g., glucose, sucrose), marker dye (e.g., organic dye), and the like. Each separate storage container for chemical components may further comprise, for example, a sensor for measuring an amount of the chemical in the container, a metering pump for delivering a measured amount of the chemical component out of the container, and associated conduits (e.g. lines, tubing). In some embodiments the solution from the system may be recycled and then supplied back into the system. However, the system may also comprise a purge drain for circumstances where it may become necessary to empty the solution from the system.

[0062] At least one sensor for monitoring levels of chemical components and other parameters may be located at any suitable location in the system, for example, in or more tanks, in a conduit that eventually leads to the growth chamber from the tank, or in a conduit that eventually leads back from the growth chamber to the tank. Fluid flow through the system may be measured and monitored to ensure that nutrient-rich solution is flowing past the sensors representing the state of the solution correctly. pH may be measured to determine the acidity of the solution. Conductivity may be measured to derive Total Dissolved Solids (TDS) content of the solution. Dissolved oxygen may be measured to determine residual O_2 in the solution as an indirect measurement of peroxide level, reducing biological oxygen demand (BOD) with peroxide or just from aeration of the solution. As above, a temperature sensor may be used to ensure that the temperature of the solution is maintained within a suitable range, and also to provide a calibration temperature for other sensors which require calibration. A colorimeter with a light source may be used to check the solution for any discolouration from algae, turbidity, undissolved solids, etc., and also to measure residual levels of enzyme or peroxide based on the rate of breakdown of a marker dye.

[0063] As would be understood, during operation at different phases of the life cycle of a plant, such as a marijuana plant, preparation of the nutrient-rich solution may be done using target levels for certain parameters, such as total dissolved solids (TDS), pH, dissolved oxygen saturation, BOD, and enzyme concentration, etc. Target levels may be further broken down into desired compound proportions based on which chemical components contribute to the target. For instance, a dosing system having a feedback loop with the controller may be used to determine how much of which chemical component to add to compensate when the target levels are out of specification and then implement any required changes. It should be understood that target levels may change due to plant uptake, evaporation etc., but also from “day” to “night”, and such levels may vary in a non-uniform or non-linear fashion within a growing cycle phase. Dosing systems may be configured to constantly and automatically determine current target levels, and work to bring all measured parameters back into a desired range if deviation occurs. For example, if the pH is too low, alkali may need to be added, if pH is too high, acid may be added, if the total dissolve solids (TDS) is too low, nutrients and/or flavour additive may be added, the dissolve oxygen is too high, the solution may be drained and then deionized water added to the drained solution and a hold period implemented to stop recirculation of the solution for a period of time, if dissolved oxygen is too low, hydrogen peroxide and/or enzymes may be added, circulation rate increased and aeration implemented (if available), if enzyme level is too high, the solution may be drained and then deionized water added to the drained solution and, if enzyme level is too low, enzyme may be added.

[0064] Root management including the ability to control root ball (root mass) size is a particularly useful aspect of the nutrient-solution delivery system. It is desirable to effectively and efficiently to control the size of the plant’s roots, including reducing chance of plugging the root zone, allowing easy removal of the plants from the plant support structure, reducing disposal cost of plant matter, using nutrients more efficiently to bias growth to marketable parts of the plant, accelerating growth of the plant by optimizing uptake abilities, and creating a more robust plant earlier in its life. The process may be used to quickly grow roots to a desired size and then slow further growth, dedicating plant energy to the above ground portions of the plant for more efficient and faster growth.

[0065] System Management Controllers

[0066] Management controllers associated with each growth chamber may be responsible for maintaining system parameters, so that failure of one growth chamber may not affect the others. The system management controllers may, via feedback loops, monitor and maintain specified conditions as outlined above, including, without limitation, lighting, air circulation, air pressure, air quality, temperature, humidity and the like. System management control may comprise a database for receiving all incoming sensor data, whereby the data may be recorded and saved. Rules or instructions for the logic of the control system and programs for growing cycles may be run. Pre-determined and adjustable set points may be provided to the management controllers, such that the system may be operated within that set of instructions until the set points are changed as the system changes to a different mode of operation, corrects for some ongoing changing condition, or in response to an operator manually making a change. System management controls may be accessed by interacting with a user interface, which may be remote with access provided through a network connection, for example through the Internet.

[0067] When signals from the sensors change, a rule engine may be processed to determine whether any modes of operation need to be changed, or if any conditions have crossed a threshold constituting an alert or an alarm. Alert or alarm may be driven by rules to determine, for example, whether such alerts are non-critical, need to be dealt with in a timely manner, or need to be escalated to alarm which demand more immediate attention. Alarms may be dispatched to an operator by any suitable method, for example via telephone, SMS messaging or the like according to operator preferences. System management controls may be semi-automated or entirely automated.

[0068] Despite all of the foregoing advancements in aeroponic plant growing systems, problems with known systems remain. For example, due to difficulties in regulating a micro-climate within the growth chamber, the systems described in the ’912 Application are maintained under negative pressure. However, operating aeroponic systems under negative pressure results in at least two problems. A first problem is that the growth chamber (i.e. the micro-climate environment) is susceptible to air or water surrounding the system being drawn into the growth chamber (i.e., towards the lower air pressure) should a leak or a problem with the air flow within the chamber occur. Any mold, spores, or bacteria present in the air could be sucked into the chamber, damaging or killing the entire crop of plants. Any increased opportunity for un-treated air or water to enter the system significantly increases the risk of contamination and threatens the viability the entire system.

[0069] A second problem relates to difficulties in configuring a system that provides easy access to the plants. For example, the ’912 Application describes a series of long rectangular “growing tubes” supporting the plants (#25, FIG. **1**). In order to access individual plants within a tube for pruning or harvesting, the entire tube has to be slidably pulled out of the growth chamber like a drawer, disrupting all of the plants within that tube and potentially exposing the entire crop to contaminants outside of the chamber. The rectangular configuration of the growing tubes may also impede access to the centrally-planted plants, discouraging their care or, in some cases, causes damage to peripherally-planted plants when trying to “reach” past them to the of the tube. Also, due to the clearance required when sliding the growing tubes from the chamber (horizontally), a significantly larger footprint is required. That is—significant space in between each growth chamber must be present for the operator to walk in between the chambers to access each of the growing tubes and to withdraw them from the chamber.

[0070] Thus, by virtue of the system design and the required operation under negative pressure, the system described in the ’912 Application renders the plants extremely susceptible to exposure from the surrounding uncontrolled environment. It would also be understood that the “drawer-like” design of the tubes limits or impairs access to piping, sensors, and air handling equipment in the system, increasing the risk of hosing becoming caught, tangled, or decoupled, and further increasing the overall footprint of the system and the cost of the space required to house the system which is often leased on the basis of the square-footage of the area. Similar drawbacks exist with other known aeroponics systems, resulting in a long-standing need for a more efficient and effective way of growing a large number of plants within a single, controlled growth chamber, while minimizing exposure of the individual plants within the chamber, and providing a compact, simple growing environment. More specifically, there remains a need in the aeroponics industry to provide plant growing systems that combine some of the features of the prior art, while overcoming their limitations and addressing their drawbacks.

[0071] It is an object of the subject apparatus and methodologies to provide an improved aeroponics system having additional features for optimizing plant growth. Accordingly, an improved aeroponics plant growing apparatus and methodologies are provided, the apparatus and methodologies enabling large scale aeroponic plant growth within a closed-loop system, minimizing contamination of the crop by either the environment surrounding the system or by operator entrance to the system for pruning and maintenance. As will be described, it is an object of the subject apparatus and methodologies that the present improved aeroponics system be specifically configured to enable quick and easy disassembly of componentry for service, cleaning, and crop change over. The present apparatus and methodologies will now be described having regard to FIGS. **1-19**.

[0072] FIG. **1** shows a perspective side view of the present improved aeroponics system **10** having a closed-loop, climate-controlled growth chamber **12** configured to receive and house a plurality of plants **14** grown without soil (only one plant per bin shown). In some embodiments, the present system may incorporate a plurality of growth chambers **12**, each chamber **12** comprising a plurality of sensors for measuring and monitoring various environmental parameters within the chamber, and configured to facilitate control over the environment by a single controller, processor, or control system.

[0073] It is an advantage of the present system that measurements acquired by various sensors (e.g., temperature, humidity, air flow, barometric pressure, etc.) can be sent as signals to a single controller, the controller then responding to the signals in a manner consistent with programming of the controller. Preferably, a plurality of sensors may be positioned directly within each plant support structure **16**, including levels for detecting fluid levels within the structures, temperature and humidity within the canopy and root zones, etc. For example, at least one temperature sensor may be used measure the air and fluid temperatures within each plant support structure **16** and/or within each growth chamber **12** (e.g., resistance temperature detectors (RTDs), gas chromatography sensors), for improved monitoring and control over the environment. At least one humidity sensor (e.g., capacitance sensors) may be used to determine the humidity and CO_2 levels within each plant support structure **16** and/or within each growth chamber **12**, for improved monitoring and control over the environment. The at least one sensor for measuring humidity may be provided within proximity of the HVAC unit, ensuring control of the humidity before and after the air passes through the growth chamber **12**. Moreover, the present system may comprise an air treatment system designed to detect and eliminate airborne contaminants and pathogens before they enter the growth chamber **12** (e.g., Air Sniper, USA).

[0074] In some embodiments, where desired, the present system may be configured such that individual chambers **12** may be positioned so as to maximize the area of growing space, without increasing the overall footprint. For example, the present system may be configured such that individuals chamber may be positioned one atop the other in a 'stacked' arrangement in any number of levels (e.g., at least three levels high, FIG. **15**), and aligned adjacent to one another (e.g., at least six chambers positioned together, FIG. **15**), for a total of at least nineteen chambers **12** (where one chamber may comprise the nutrient delivery system). Advantageously, the 'stackable' nature of the present system allows for as many as three levels of growing space, providing a compact system having a reduced overall environment footprint without jeopardizing access to any of the plants **14** growing within the system. In some embodiments, chambers **12** may be sized according to user specifications, and for example may be approximately 8 ft (wide)×12 ft (long)×7 ft (high), or any other desired dimensions. It should be appreciated that, regardless of the configuration, it is an advantage that each of the chambers **12** of the present system may be individually monitored and controlled by one controller, computer, processor or the like, whereby parameters within each chamber **12** may be individually measured and controlled via separate feedback loop processing (see, for example, FIGS. **15-19**).

[0075] Having regard to FIGS. **1** and **2**, each growth chamber **12** may be enclosed by a protective envelope or "wall" **13** (i.e., the wall including four sidewalls, a roof and a floor). Wall **13** may comprise any appropriate material for use in the aeroponic industry, including any non-porous or air-tight, light-reflective material suitable for the secure, sterile cultivation and management of plants. Wall **13** may comprise one or more ports enabling the control of the environment within the chamber **12**, and where desired, providing access to the plants **14** being cultivated therein. In some embodiments, the wall **13** itself may be further enveloped, forming a vestibule-type space serving as an additional buffer zone between the environment and the growth chamber **12** (not shown).

[0076] According to embodiments, the present system **10** is configured to house a large crop of plants **14** within each climate-controlled growth chamber **12**. For example, the system **10** may be configured to receive a plurality of plant support structures, referred to herein as "tubs" or "bins" **16**. In some embodiments, each growth chamber **12** may be configured to receive at least six plant support bins **16**. Bins **16** are configured to receive and support a plurality of individual plants **14** within close proximity. In some embodiments, each bin **16** is configured to provide an upper "canopy zone" **18** for supporting the plant canopy and exposing the plants **14** to the lights **15** thereabove, and a separate lower "root zone" **19** for supporting the plant roots or root ball and preventing exposure of the roots to the lights **15**.

[0077] Bins **16** may be adapted to receive a plurality of plants **14**, such as at least twenty-one plants **14**, for upwards of one hundred twenty-six individual plants **14** being cultivated at one time within each chamber **12**. Only one plant **14** per bin **16** is shown for illustrative purposes. It is contemplated that each bin **16** may be configured to support as many or as few plants **14** as may be desired by the user, and that proximity of the plants **14** to one another may depend upon the strain of plant being cultivated.

[0078] Having regard to FIGS. **3** and **4**, plant bins **16** may be sized and shaped in order to maximize grow space and to minimize light or air flow dead-zones within the chamber **12**. Moreover, bins **16** may be specifically sized and shaped in order to provide easy access to each individual plant **14**, thereby reducing disruption to the crop during pruning and harvesting of individual plants **14**. In some embodiments, bins **16** may be configured to be rotatable—that is, each bin **16** may be designed to be rotated about a central axis independently from one another (e.g. each bin **16** being rotatable about a central point such as a drain hole H, as will be described in more detail). It is contemplated that each bin **16** may be individually and freely rotated.

[0079] By way of background, attempts have been made in the aeroponic plant growing industry to provide rotatable systems, such systems, for example, being described in at least U.S. Patent Application Pub. No. 2012/0090236, U.S. Patent Application Pub. No. 2009/015144, and U.S. Patent Application Pub. No. 2019/0082619. Such systems, however, describe discrete individual plant growing structures that are only able to grow a small number or density of plants at one time. Such systems also require that the rotation of the plants be motorized and automated, and that the rotation is programmed to occur relative to, for example, light and air sources in order to provide consistent exposure to resources (e.g., for entirely robotic cultivation). Due to the individualized nature of each rotating plant "pod", prior art growing systems necessitate individualized light and irrigation system for each pod, complicating the system componentry and increasing the footprint required for the overall system. There remains a need for a system that overcomes the deficiencies of known aeroponics systems, enabling the growth of large crops of plants at one time.

[0080] It is an object of the present system to provide for independent, manual rotation of each plant support structure **16** for the purposes of improving access to the plants **14** for pruning, inspection, and harvesting purposes. Where desired, operators may simply enter the chamber **12** and rotate only those bins **16** where plants **14** require attention, eliminating the need for the operator to reach across grow tubes, or to withdraw the plants from the chamber **12**. Such enhanced accessibility to the plants **14** can reduce the time the plants are exposed air conditions outside of the growth chamber **12**. Rotatable bins **16** also serve to prevent the clearance required around the bins **16** (i.e., with only space required around the outside of each grouping of bins **16**), maximizing the total grow area compared to conventional fixed-tray systems (such as those described in the '912 Application above).

[0081] Although not required, it is contemplated that the bins **16** may further be rotated with respect to, for example, light and air sources within the chamber **12** (i.e., preventing dead zones). As may be appreciated, flexible maneuvering of plants **14** inside growth chamber **12** relative to, for example, light and air sources can allow even exposure to resources, improving the overall health and yield of plants **14**.

[0082] Having regard to FIGS. **5** and **6**, in some embodiments, the present plant support structures or 'bins' **16** may be generally cylindrical in shape, having a circular cross section and having a bottom wall **16***a* and a sidewall **16***b* encircling its circumference. Bottom wall **16***a* may form drain hole H, and may be generally sloped downwardly encouraging fluid collecting on the bottom wall **16***a* to flow towards drain hole H.

[0083] Bins **16** may be rotatable about a turntable or track **30** (i.e., a lazy-susan style design), whereby bins **16** may be supported by the track **30** for rotation. Bins **16** may be configured to be removably mounted onto the track **30**, and in some embodiments may form an annular groove **31** for corresponding with track **30**. In operation, an operator may simply grasp a bin **16** about its sidewall **16***b* and manually rotate same until it reaches the desired position, without interruption to the irrigation system or disconnection from any componentry. Importantly, the bin **16** may be gently rotated about track **30**, minimizing disruption to the plants **14** positioned within the bin **16**. As will be described in more detail, bins **16** may also be configured for easy removal from the growth chamber **12** (i.e., via a quick-release pin mechanism) for cleaning and/or maintenance in between plant growth cycles.

[0084] Having regard to FIGS. **7**A and **7**B, bins **16** may be adapted to receive and support at least one plant support divider **20**, such divider **20** being rotatable with the bin **16**. When dividers **20** are mounted within a bin **16**, the dividers **20** create a plant-support tray or disc that extends around all or substantially all of the circumference of the bin **16** (i.e., divider **20** may be supported by and extend around the sidewall **16***b* of the bin **16**). In some embodiments, bin sidewall **16***b* may comprise an annular flange or collar **16***c* for supporting divider **20**, such that divider **20** can be easily removed from the bin for cleaning and maintenance, or where access to the irrigation system is required.

[0085] In some embodiments, the upper canopy zone **18** may be configured to provide at least one canopy support structure, such as a plant trellis **21**, to provide easy access to the canopy of the plants **14** for pruning and harvesting, while minimizing disruption to the sensitive roots therebelow. Annular flange **16***c* may form at least one hole for slidably receiving and supporting trellis **21**, although any other means for securely connecting a plant support structure to bins **16** are contemplated.

[0086] In some embodiments, dividers **20** may be configured to support a plurality of plants during their growth cycle. More specifically, dividers **20** may form one or more apertures **22** configured to receive at least one cup or basket **24** for supporting the stem and roots of the plants **14**. For example, as would be known in the art, each aperture **22** may be configured to receive at least one root mesh cup **24** having a closed-cell foam disc (i.e., a root guard) for removably supporting the stalk of the plant **14**, and mesh cup or basket suspended therebelow for enclosing the roots of the plant dangling inside. Dividers **20** may be manufactured from non-porous or semi-porous material, such that misting of the nutrient-rich solution is limited to the roots of the plants **14** growing below the dividers **20**. Dividers **20** are also manufactured such that parameters within the "root zone" **19** may be independently monitored and controlled within each bin **16**. FIG. **7**A provides a top down view of the dividers **20** positioned within bins **16**, one bin being shown in partial cross-section view (again only one plant **14** being shown in each bin **16** for illustrative purposes only).

[0087] Having regard to FIG. **8**, each plant support bin **16** (and corresponding track **30**, as described above) may be supported by a base **17** for raising the bins **16** above the chamber floor **11**. Bases **17** may be manufactured from any suitable material for supporting bins **16**, and configured such that the height of the base **17** ensures that each bin **16** is within sufficient proximity to artificial lighting **15** thereabove.

[0088] Base **17** may be any size or shape suitable for supporting rotatable bins **16**, with a rectangular base **17** being shown for illustrative purposes. In some embodiments, base **17** may comprise an upper portion **17***a* configured to receive bin **16**, and a lower portion **17***b* configured to position the base **17** on the chamber floor **11**. Upper and lower portions **17***a*,**17***b* of the base **17** may comprise a plurality of support bars **17***c* therebetween, for reinforcing or strengthening the base **17**.

[0089] Having further regard to FIG. **8**, base **17** may also serve to support irrigation componentry **40** for the present system's nutrient delivery system **40**, also referred to herein as the "irrigation system". More specifically, upper portion **17***a* of each base **17** may be configured to support fluid communication lines **40** into **41** and out of **43** each bin **16**. Fluid lines may establish communication with a delivery header **42**, such headers **42** comprising one or more valve, such as a modified rotating coupler **50** (as described in more detail below). Fluid lines **41**,**43** may each have check valves positioned along the lines, such valves being associated with fluid flow sensors for monitoring and controlling fluid flow through the lines into and out of each bin **16**. Each header **42** may be in fluid communication with at least one manifold **44**, positioned within the root zone **19**, for distributing the nutrient-rich solution to the plants **14**. In that regard, the present system is configured to provide one irrigation system that branches to a plurality of chambers **12**, and then further to a plurality of bins **16** within each chamber **12** (see FIGS. **15**-**19**).

[0090] Advantageously, the system provides one closed-loop irrigation system operative to irrigate a large crop of plants on an individualized basis (i.e., to cycle fluids into and out of each plant support structure **16**). It should be appreciated that such a configuration ensures that, where desired, irrigation to the plurality of plants **14** within one bin **16** may be modified or ceased, without impacting plants **14** in other bins **16**. Moreover, where irrigation to one chamber **12** is modified (i.e., at the end of the growth cycle), irrigation to the remaining chambers **12** may continue uninterrupted. The present nutrient solution delivery system may also comprise one or more air and/or fluid chillers (e.g., coiled heat exchangers, or the like), to more accurately maintain the temperature of the nutrient-rich solution, which in turn serves to control the temperature in the root zone. As should be appreciated, the temperature within the root zone **19** is critical. It follows that stringent control of fluid temperature is also of critical importance (e.g., it is desirable to maintain the temperature of the oxygen-rich water solution within the root zone **19** at or near 18° C., or approximately 4° C. lower than the canopy zone **18**). In preferred embodiments, the present system may comprise systems for injecting cool air into the root zone **19**, such that temperatures within the root zone **19** are strictly controlled. Manifold **44** may support one or more nozzles (not shown) operative to deliver by "mist" or "spray" the nutrient-rich solution to the root zone **19** (e.g. under low and high pressure, or via 'fogponics'). Nozzles may comprise any suitable spray or mist-type nozzle as desired, such nozzles being selected, for example, based upon coverage of the solution to the root zone **19**, or based on droplet size delivered through the nozzles, etc.

[0091] According to embodiments, the present system may be specifically configured to provide rotatable bins **16**, whereby bins **16** can be manually rotated about a central axis without interruption to the irrigation system supplying nutrient-rich solution to each bin **16** (i.e., bins **16** may be rotated while the nutrient-rich solution is being delivered, and without disconnection from fluid communication lines into **41** and out of **43** each individual bin **16**). According to embodiments, the present system **10** comprises at least one valve, such as modified rotating coupler **50**, sealably positioned within the drain hole H of each bin **16**, the coupler **50** serving as a rotatable bi-directional fluid passageway establishing communication between the irrigation system **40** and bins **16**. More specifically coupler **50** operates to connect the fluid communication lines **40** of the irrigation system with the manifold **44** within the root zone of the bin **16**. Coupler **50** may be further configured to enable quick and easy release of the manifold **44** from the bin **16**, and/or of the bin **16** from the base **17**, for easy cleaning and maintenance of the componentry. Coupler **50** will now be described in more detail having regard to FIGS. **9-14**.

[0092] FIG. **9** shows a perspective partial cross-section side view of coupler **50** positioned within bin **16**, and connected to irrigation system **40** and manifold **44**. More specifically, coupler **50** may be sealably positioned within drain hole H, such that its lower end may be in fluid communication with the irrigation system **40** below the bin **16**, and its upper end may be in fluid communication with the manifold **44**. Fluid flow into and out of the bin **16** via coupler **50** thus provides a closed-loop system, whereby fluids can be recovered and recycled, or discarded (as desired). Coupler **50** may be specifically configured to be rotatably mounted within the bin **16**, while providing a first fluid passageway for delivery of the nutrient-rich solution to the plants **14**, and a second fluid passageway for removing excess solution draining from the plants **14**. Advantageously, coupler **50** may be specifically configured for quick-release in at least two ways, the first where it is desirable to remove manifold **44** from a bin **16**, and second where it is desirable to disconnect and remove a bin **16** from the irrigation system **40** therebelow.

[0093] Having regard to FIGS. **10**A and **10**B, coupler **50** may comprise housing **60** for sealably connecting the coupler within the bin **16**, and further for connecting a stationary coupler shaft **70**, in fluid communication with the irrigation system, with a rotatable manifold (nozzle) mount **80**, in fluid communication with manifold **44**. Coupler **50** may be secured in positioned by any means known in the art, such as by lock nut **100** which may be threadably engaged with housing **60** from above bottom wall **16***a*. Advantageously, the present coupler **50** may be configured such that, when securely installed in the bin, housing **60**, lock nut **100** and bin **16** may all rotate together (provided that lock-springs **90** are in place). As will be described, coupler **50** may be configured such that stationary shaft **70** may be releasably connected with housing **60**, such as by a first quick-release connection. Coupler **50** may also be configured such that rotatable spray manifold mount **80** may be releasably connected with housing **60**, such as by a second quick-release connection. More specifically, such quick-release connection may comprise a first quick release lock-pin between housing **60** and shaft **70**, and a second quick release lock-pin between housing **60** and nozzle mount **80**.

[0094] Housing **60** may be sized to be slidably received within hole H of the bin **16**, and may form annular flange **64** for sealingly abutting bottom wall **16***a* of the bin **16**. During assembly, flange **42** serves to prevent housing **60** from passing through hole H upwardly into bin **16** and, along with lock nut **100**, may further provide means for securely clamping housing **60** to bin **16** (i.e., each of housing **60** and lock nut **100** provide holes for tightening the clamping connection during assembly, or loosening the connection during disassembly). In some embodiments, flange **64** and nut **100** may sealingly engage bottom wall **16***a* for preventing fluid flow through hole H. Flange **64** may form annular groove **65** for receiving an annular seal therein (e.g., O-ring and/or face seal (gasket)). It is understood that other means for sealingly engaging modified valve **50** within bin **16** are contemplated, as may be appropriate.

[0095] Having regard to FIGS. **11**A, **11**B, and **11**C, housing **60** may form a substantially tubular body, the body having a cylindrical sidewall **62** with an internal surface **61** and an external surface **63**, the sidewall **62** forming longitudinal bore **66** therethrough. As will be described, the internal diameter of bore **66** may be sized for slidably receiving and forming a sealed connection between coupler shaft **70** and nozzle mount **80**. In some embodiments, the internal diameter of bore **66** may be consistent along its entire length. In other embodiments, the internal diameter of bore **66** may increase incrementally at each end of bore **66**, such that internal surface **61** of sidewall **62** forms shoulders for abutting and preventing movement of coupler shaft **70** and spray manifold mount **80** within bore **66**. For example, internal surface **61** may form upper annular shoulder **67** for abutting an restricting movement of nozzle mount **80**, and may form lower annular shoulder **69** for abutting and restricting movement of coupler shaft **70**. Moreover, as will be described, shoulders **67**,**69** align with annular grooves configured to receive a lock-spring **90**. In that regard, about its upper and lower ends, sidewall **62** of housing **60** may form a plurality of pin holes **91** for receiving lock-spring **90** for quick-connection and release of housing from shaft **70** and of housing from mount **80**.

[0096] External surface **63** may form at least one annular recess for removably receiving means for filtering fluids draining from bin **16**. In some embodiments, means for filtering fluids may comprise an annular screen **68** (see FIG. **10**A,**10**B). Screen **68** may be positioned at or near the bottom wall **16***a*, such that fluids flowing towards hole H pass through screen **68** before entering coupler **50**. Screen **68** may be sealingly received within the recess on external surface **63**. Moreover, sidewall **62** forms fluid port **62***a* therethrough for draining fluids passing through screen **68** into coupler **50** (see fluid flow arrows, FIG. **10**B).

[0097] Having regard to FIGS. **12**A, **12**B, and **12**C, coupling shaft **70** may form a substantially tubular body **72**, the body **72** forming at least two distinct fluid passageways **71**,**73** therethrough. Passageways **71**,**73** may be L-shaped fluid passageways and may correspond, respectively, with the inlet and outlet fluids lines **41**,**43**, of the irrigation system **40**. In that regard, nutrient-rich solution delivered from the irrigation system **40** through line **41** enters coupler **50** and passes into bin **16** via L-shaped fluid passageway **41** via manifold **44** (and nozzles, not shown). Solution that is not absorbed by the plants **14** will drain back through coupler **50** through L-shaped fluid passageway **73** and out through return line **43** of the irrigation system (arrows, FIG. **10**B). As should be appreciated, fluid draining from bin **16** into line **73** may first pass through filtering means (e.g. screen **68**), or other filters as desired. It should be appreciated that upper end of L-shaped fluid passageway **73** is plugged or sealed, such that no fluid can enter into the passageway **73** but through screen **68**.

[0098] Body **72** may comprise an upper portion **74** and a lower portion **75**, the upper portion **74** being substantially cylindrical in shape and being sized so as to be slidingly received within bore **66** of housing **60**. In that regard, the outer surface of upper portion **74** may form at least one annular groove **77***a,b,* . . . *n* for receiving an annular sealing member (e.g., O-rings), thereby preventing fluid flow through annulus of bore **66**. The outer surface of upper portion **74** may, about its lower end, further form annular groove **79** for receiving lock-spring **90**. Accordingly, it is desirable that annular grove **79** correspondingly align with shoulder **69** of housing for receiving lock-spring **90**.

[0099] The lower portion **75** of body **72** may be being enlarged, relative to the upper portion **74**, for accommodating the elbow portion of L-shaped fluid passageways **71**,**73**. L-shaped fluid passageways **71**,**73** may, respectively, form an inlet **76** establishing connection between fluid delivery line **41** and fluid passageway **71** for transmitting nutrient-rich solution into bin **16**, and an outlet **78** for establishing connection between fluid drain lines **73** and **43**, for removing fluid from the bin **16** (see arrows depicting fluid flow, FIG. **12**C). It would be understood that any connection means appropriate in the art, such as threaded connection means (not shown), may be used to establish fluid flow from the irrigation system **40** into and out of coupler **50**.

[0100] Having regard to FIGS. **13**A, **13**B, and **13**C, spray manifold mount **80** may form a substantially tubular body **82**, such body **82** having a sidewall with an internal surface **81** and an external surface **83**, the internal surface **81** forming bore **84**. Bore **84** may be configured to establish fluid communication between input fluid passageway **71** of coupler **50** and fluid control manifold **44** for distribution of fluids (i.e., via misting nozzles, or the like). In some embodiments, manifold mount **80** may be configured to receive fluids delivered from input fluid passageway **71** and to divert the fluid stream into one or more directions via a plurality of orifices **88**.

[0101] More specifically, body **82** may comprise an upper portion **85**, for mounting manifold **44** (i.e., such manifold **44** extends substantially horizontally therefrom), and a lower portion **86**, for being slidably received within housing **60**. Upper portion may form an annular shoulder for abutting upper end of housing **60**, preventing movement of manifold mount **80** too far into bore **66** of housing **60**. Upper portion **85** may form a plurality of orifices **88**, such that nozzles can be mounted to spray fluids in any direction, as may be desired. It would be appreciated that orifices **88** may be sized and shaped in any manner so as to enable consistent fluid flow rates therethrough.

[0102] As above, lower portion **86** may be configured to be slidingly received within bore **66** and to form a sealed connection with housing **60**. External surface **83** may form at least one annular groove **87** for receiving an annular sealing member (e.g., O-rings), thereby preventing fluid flow through annulus of bore **66**. The external surface **83** may, about its upper end, further form annular groove **89** for receiving lock-pin **90**. Accordingly, it is desirable that annular groove **79** correspondingly align with shoulder **67** of housing for receiving lock-spring **90**.

[0103] Having regard to FIG. **14**, the present quick-release mechanism may comprise a lock-spring **90**, or the like, configured to be slidingly received within pin holes **90**. As such, an operator desiring to disengage manifold mount **80** from valve housing **60** may simply pull a first lock-spring **90** from pin holes between manifold mount **80** and housing **60**. An operator desiring to disengage valve housing **60** from shaft **70** may simply pull a second lock-spring **90** from pin holes **91** between housing **60** and shaft **70** (first lock-spring may be in place, or may have already been disengaged). In some embodiments, lock-spring may be formed from a metal wire or other suitable material, the wire being bent into two coiled loops. In that regard, lock-spring **90** may be releasably inserted into pin holes **91** for securing the components of the coupler **50** together, or removed therefrom for quick-release disengagement of the coupler **50** components.

[0104] In operation, a method for growing plants aeroponically is provided, the method comprising providing a plurality of rotatable plant support structures **16** releasably positioned within at least one climate-controlled plant growth chamber **12**, each plant support structure **16** being independently rotatable about a central axis, and having at least one valve or coupler **50** sealably positioned therein (e.g., in drain hole H). Each plant support structure **16** may contain a divider **20** for dividing the structure **16** into an upper zone **18** for supporting a canopy portion of the plants **14**, and a lower zone **19** for supporting a root portion of the plants **14**. The method may further comprise providing a nutrient-rich solution to the root portion of the plants **14** in the lower zone **19** and retrieving excess solution draining therefrom. The method may further comprise providing a plurality of sensors (not shown) for measuring the climate within each growth chamber **12** and generating signals indicative thereof, such signal being provided to a controller operative to receiving the signals from the sensors and, based on the signals, controlling the climate within each growth chamber **12**.

[0105] It would be understood that the present methods comprise planting a plurality of plants **14** within each plant support structure **16** and supplying the root portion of the plants **14** with the nutrient-rich solution, and where desired, rotating one or more plant support structures to access the plurality of plants **14**.

[0106] The present methods may further comprise providing at least one quick-release mechanism in each of the plant support structures **16** for removal of the plant support structures **16** from the growth chamber **12**. The at least one quick-release mechanism may comprise a first lock-spring **90** for removing manifold **44** from the plant support structures **16**, and a second lock-spring **90** for removing the plant support structure **16** from the growth chamber **12**.

[0107] Although a few embodiments have been shown and described, it will be appreciated by those skilled in the art that various changes and modifications can be made to these embodiments without changing or departing from their scope, intent or functionality. The terms and expressions used in the preceding specification have been used herein as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding equivalents of the features shown and the described portions thereof

We claim:

1. An aeroponic plant growing apparatus, the apparatus comprising:
at least one climate-controlled growth chamber containing:
a plurality of plant support structures for receiving and supporting a plurality of plants, each plant support structure independently rotatable about a central axis,
each plant support structure having a divider for dividing each plant support structure into an upper zone for supporting a canopy portion of the plant, and a lower zone for supporting a root portion of the plant, the lower zone of each plant support structure having at least one manifold for delivering the nutrient-rich solution to the root portion of the plants;
a nutrient delivery system in fluid communication with each plant support structure, the nutrient delivery system configured to deliver a nutrient-rich solution to the lower zone of each plant support structure, and to retrieve excess solution draining therefrom;
a plurality of sensors to measure the climate within each growth chamber, and to generate a signal indicative thereof; and
a single controller operative to receive the signals from the plurality of sensors, and programmed to individually control the climate within each of the plurality of growth chambers based on the signals;
wherein each plant support structure has at least one valve sealably positioned within the structure for establishing fluid communication between the nutrient delivery system and the at least one manifold for delivery of the nutrient-rich solution to the root portion of the plants.

2. The apparatus of claim **1**, wherein the growth chamber is enveloped by a wall comprising a non-porous, light-reflective material.

3. The apparatus of claim **1**, wherein the plurality of plant support structures are each rotatable while in fluid communication with the nutrient delivery system.

4. The apparatus of claim **1**, wherein the plurality of plant support structures comprises at least six plant support structures.

5. The apparatus of claim **1**, wherein the dividers may be removably mounted within the plant support structures.

6. The apparatus of claim **1**, wherein the dividers form apertures for receiving and supporting the plurality of plants.

7. The apparatus of claim **1**, wherein the at least one plant support structures are each mounted onto a base for supporting the nutrient-rich delivery system for cycling fluids to each at least one plant support structure.

8. The apparatus of claim **1**, wherein some of the plurality of sensors are positioned within the lower zone to maintain the root portion of the plants at a temperature lower than the upper zone.

9. The apparatus of claim **1**, wherein the valve comprising a rotating coupler having a housing for releasably connecting a stationary coupler shaft with a rotatable manifold nozzle mount.

10. The apparatus of claim **9**, wherein the housing is releasably connected to the stationary coupler shaft, and releasably connected to the rotatable manifold nozzle mount.

11. The apparatus of claim **10**, wherein the releasable connection between the housing and the stationary coupler shaft comprises a first quick-release lock-spring.

12. The apparatus of claim **10**, wherein the releasable connection between the housing and the manifold nozzle mount comprises a second quick-release lock-spring.

13. The apparatus of claim **1**, wherein the at least one growth chamber comprises a plurality of growth chambers configured in a stacked arrangement.

14. A method for growing plants aeroponically, the method comprising:
providing a plurality of rotatable plant support structures releasably positioned within at least one climate-controlled plant growth chamber,
each plant support structure being independently rotatable about a central axis, and having at least one valve sealably positioned therein,
each plant support structure having a divider for dividing the structure into an upper zone for supporting a canopy portion of the plants, and a lower zone for supporting a root portion of the plants;
providing a nutrient-rich solution to the root portion of the plants in the lower zone and retrieving, via a closed-loop system, excess solution draining therefrom;
providing a plurality of sensors for measuring the climate within each growth chamber and generating signals indicative thereof;
providing a controller operative to receiving the signals from the sensors and, based on the signals, controlling the climate within each growth chamber;
planting a plurality of plants within each plant support structure and supplying the root portion of the plants with the nutrient-rich solution; and
where desired, rotating one or more plant support structures to access the plurality of plants.

15. The method of claim **14**, the method further comprising providing at least one quick-release mechanism in each of the plant support structures for removal of the plant support structures from the growth chamber.

16. The method of claim **15**, wherein the at least one quick-release mechanism may comprise a first lock-spring for removing a manifold nozzle mount from the plant support structures.

17. The method of claim **15**, wherein the at least one quick-release mechanism may comprise a second lock-spring for removing the plant support structures from the growth chamber.

18. The method of claim **14**, wherein the method further comprises maintaining the lower zone of the plant support structure at a lower temperature than the upper zone.

19. The method of claim **18**, wherein the temperature within the lower zone is approximately 18° C.

20. The method of claim **14**, wherein the controller comprises a single controller, processor, or control system for controlling the plurality of plant growth chambers.

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