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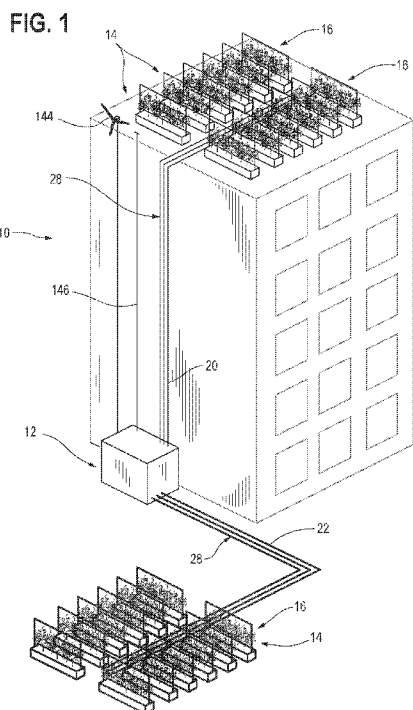
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(57) Abstract: A system for providing nutrients to a plant may support the plant with the root system exposed and accessible in a controlled environment within a structure, effecting interaction between a carrier fluid and a soil-based medium to transport nutrients from the soil-based medium to targeted plants. The soil-based medium may comprise organic soil at or near grade level and/or other media at other elevations. In some embodiments, the system includes a structure that comprises a roof-mounted frame placed in a location that can expose portions of plants to natural sunlight and a lightweight, aerated, humidity controlled enclosure around the root system.



SYSTEM FOR SUPPORTING PLANT LIFE

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Application No. 63/472,917 filed June 14, 2023, the disclosure of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] This document relates to systems for providing nutrients to plants, including methods or processes to provide nutrients, as well as apparatus for providing nutrients.

BACKGROUND

[0003] Population increases and accompanying expansion of residential communities and metropolitan areas often involve conversion of farmland to non-agricultural uses, as well as increased distances from farm to table. Reductions in arable land and increased transportation challenges tend to increase difficulties and expenses associated with providing high-quality produce to consumers. These challenges may be exacerbated with respect to products of organic farming, which may involve lower yields per acre as compared with non-organic farming.

[0004] Urban farming and home gardening can enable production of high-quality produce close to consumers, but availability of suitable areas for growing is limited in urban environments. Rooftops may offer good exposure to natural sunlight, but many rooftops are not capable of supporting a large volume of soil. Some roofs have been designed to handle significant snow loads, e.g., loads on the order of about 20 lbs/ft², but soil at a depth of about one foot can weigh much more, e.g., 50-100 lbs/ft². Thus, the structural limitations of many buildings make them unsuitable for rooftop farming. Raising loads of soil to rooftop gardens poses additional challenges.

[0005] Selecting plants with shallow rooting requirements and/or reinforcing roof structures can be helpful in addressing the weight issues, but these are not ideal solutions. Adding structure to buildings to carry the weight of deep soil may be far too expensive to be commercially feasible. In one case, a structure to support an 820 square foot garden with 8" deep soil, completed in 2014, reportedly cost \$150,000. <https://umbrellahouse.nyc/umbrella-house-garden/>

[0006] Hydroponic and aeroponic systems can enable plants to be grown in rooftop gardens without requiring beds of soil. However, the costs associated with these systems, e.g., costs associated with specialty liquid fertilizers, may be undesirably high. Also, these systems do not

provide certain benefits associated with traditional farming, particularly organic farming. Some products of traditional farming are thought to provide health and nutrition benefits that are not provided by hydroponic or aeroponic systems. Also, traditional organic farming processes are thought to provide environmental benefits that are not provided by hydroponic and aeroponic systems.

[0007] In some hydroponic and aeroponic systems, essential nutrients are made absorbable by using man-made chelates, not by natural chelation processes associated with organic soil life. Resulting artificial aqueous nutrient solutions may be inherently biologically unstable. A hydroponic/aeroponic system tank may require continuous or frequent pH balancing, and may need to be drained every few weeks to maintain a healthy root environment. In contrast, quality organic soil may be naturally balanced and continuously regenerated through soil life activity with little or no human energy input or waste. Further, soil-grown produce may have superior flavor and nutritional content as compared with hydroponically-grown produce.

SUMMARY

[0008] The systems, methods and apparatus described herein include plant nourishment systems for providing nutrients, e.g., one or more essential elements such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), nickel (Ni), chlorine (Cl), and other non-essential elements in a plant-available form to a plant.

[0009] In some embodiments, a system employs a liquid and gas permeable soil-based medium comprising particulate organic matter, minerals, one or more liquids, and organisms. The soil-based medium is mixed, moistened and aged using a soil building technique until the medium is well-suited for particular plants. In some embodiments, suitable and/or optimal components and soil building techniques may be determined by elemental testing and experimental data for each type of plant.

[0010] In some embodiments, the system includes a structure supporting the plant and maintaining a controlled environment that protects root systems and facilitates growth thereof. In some embodiments, the root system is exposed and accessible within the structure to facilitate transfer of nutrients to the root structure and to facilitate visual inspection of the root system.

[0011] In some embodiments, the system effects interaction between a carrier fluid and a soil-based medium to transport nutrients from the soil-based medium to targeted plants. This may involve effecting flow of a carrier liquid intermittently and/or uniformly to maintain gas

permeability suitable for soil organisms and to cause entrainment of a portion of the soil-based medium in the carrier liquid, then into contact with a root system in a manner that provides a film of carrier liquid on at least part of the root system and effects transfer of dissolved nutrients and particulate matter from the soil-based medium to the root system. This may create a microenvironment at the rhizosphere, i.e., the root zone or soil-root interface, similar to typical organic root-in-soil growing techniques but without the related weight and bulkiness at the plant site.

[0012] The soil-based medium may comprise organic soil at or near grade level and/or other media at other elevations. The carrier fluid may include water and/or other fluids.

[0013] In some embodiments, the plant nutrition system includes one or more housing structures, each of which comprises a roof-mounted frame placed in a location that can expose portions of plants to natural sunlight and a lightweight, aerated, humidity-controlled enclosure around the root system. In some embodiments, the structure may be supported by a residential building such as a single-family home; a multi-unit apartment or condominium building; a townhouse; a restaurant building; an office building; a food processing or distribution facility; or other building. Each housing structure may be supported on a roof, balcony, or other support structure.

[0014] In some embodiments, the system filters a water-based carrier liquid to retain certain particles while leaving other particles entrained, pumping the carrier liquid to the enclosure while maintaining the flow of carrier liquid as a film bounded by air for gas exchange, then spraying, with relatively low velocity to prevent root damage, at least a portion of the carrier liquid and entrained particulate matter onto the root system. In some embodiments, spraying the carrier liquid and entrained particulate matter may comprise generating a mist comprising droplets of carrier liquid traveling at, e.g., 0.5 to 5 feet per second (fps), or about 0.5 fps, or about 5.0 fps, or 0.5 to 4.5 fps, or 1.5 to 4.0 fps, or about 2.5 to 3.0 fps within plant enclosures to transfer water and particulates to roots without damaging the roots. In some embodiments, the flow velocity may be, e.g., 10-50 fps, 15-45 fps, 20-40 fps, 25 to 35 fps or about 10 fps, or about 50 fps, or about 30 fps in the mist supply pipes. In some embodiments, this spraying comprises effecting flow of the carrier liquid and entrained particulate matter from a conduit onto an intermediate surface such that droplets of the carrier liquid are caused to travel from the intermediate surface to the root system, wherein the film of carrier liquid on the root system enables absorption of water and nutrients by the root system and wherein the film is bounded by air. In some embodiments, the

intermediate surface may comprise a moving surface, e.g., a surface on a disc having a diameter of 3 in. to 12 in. rotating at 1000 to 4000 rpm.

[0015] The plant nourishment system may include a return system that collects excess carrier liquid, particulate matter and root exudates, aerates the excess carrier liquid, and returns some or all of the excess carrier liquid, particulate matter and root exudates to the soil-based medium. Addition of root exudates to the soil-based medium may assist in decomposition, moisture retention and natural nutrient conversion processes typically found in soil. These nutrient conversion processes may be modulated by the root exudates to control the chelation, inhibition and retention of nutrients for absorption as demanded by the plant in real-time.

[0016] In some embodiments, the soil-based medium and plant root zones may include organic soil life such as actinomycetes, algae, archaea, bacteria, fungi, protozoa, and/or larger soil fauna such as arthropods, earthworms and nematodes. This may assist with decomposition, aeration and nitrogen fixation as well as further assisting the natural soil nutrient conversion processes taking place therein.

[0017] In some embodiments, effecting flow of carrier fluid can be conducted continuously and without interruption for an indefinite number of days without discarding or "flushing" the carrier fluid as may be done in hydroponics/aeroponics.

[0018] In some embodiments, the plant produces one or more products useful for providing nutrition, health benefits or other benefits to humans.

[0019] In some embodiments, the plant nourishment system includes soil-based medium in stacked soil beds wherein effecting flow of carrier fluid includes effecting flow sequentially into and out of the stacked soil beds to maintain soil porosity for aeration and flow.

[0020] In some embodiments, a process includes creating a soil-based medium by aging, aerating, and supplying water to a mixture of organic matter and minerals in a bulk storage unit.

[0021] In some embodiments, effecting flow of carrier fluid through the soil-based medium comprises effecting flow of water through a rotating drum containing the soil-based medium.

[0022] Some embodiments comprise maintaining a buffer layer of moist soil in the enclosure, and/or maintaining soil life in the enclosure.

[0023] In some embodiments, the system provides some or all of the benefits of organic soil while eliminating about 80% to 90% of root zone soil weight associated with traditional organic farming. In some embodiments, this allows plants to grow on top of structures that normally could not support the full weight of traditional soil techniques. In some embodiments, this also allows

for growing in difficult to reach areas using a soil-based medium without the need for bringing the full volume/weight of soil at one time (staged soil growing). In some embodiments, instead of roots growing into a heavy mass of soil to seek nutrients, they grow bare within a lightweight, humidity-controlled, aerated enclosure. As the roots grow, they are continuously coated with a layer of fine filtered soil particles, soil life and dissolved nutrients while larger soil particles (mostly unusable mass) stay behind to be processed into smaller particles. Unlike hydroponics/aeroponics, in some embodiments, the roots are growing within a film or coating of soil and water. The film or coating may be nearly invisible to the naked eye, and may emulate natural transmission of nutrients to roots as occurs in traditional farming by soil contacting the roots, and by water filtered through the soil. In some embodiments, the roots are never submerged as they are in some other hydroponic, aeroponic or compost tea systems. In some embodiments, throughout the entire system cycle, the soil and water always exist as a film at the boundary of air (as with soil). In some embodiments, due to the small particle size and high oxygenation, soil life on the root surface can convert the solids to plant nutrients at a faster rate than traditional soil. In some embodiments, the environment within the root enclosure may be analogous to what roots experience inside underground soil pore spaces while achieving reduced weight, greater available volume for root growth and greater aeration of the root zone, reducing the amount of total soil required to start and continue growing.

[0024] The systems described herein are believed to be superior to traditional farming in some ways due in part to the fact that in traditional farming, most of the mass of the soil in which plants are grown is not immediately utilized by the plants while growing. Most of the soil's mass is within relatively large particles while the roots, bacteria and fungi can only act on the surfaces of the particles. Excluding larger, heavier soil particles may make the system more practical in an urban environment.

BRIEF DESCRIPTION OF DRAWINGS

[0025] Fig. 1 provides an overview of an example of a plant nutrition system.

[0026] Fig. 2 is an enlarged view of an array of plants with root systems supported within housing structures.

[0027] Fig. 3 is an enlarged view of apparatus for creating a nutrient-rich fluid and effecting flow thereof.

[0028] Fig. 4 is a sectional view of a portion of Fig. 2.

[0029] Fig. 5 is a schematic view of a cascading siphon system.

DETAILED DESCRIPTION

[0030] Examples of plant nutrition systems are described below.

[0031] Figs. 1-3 illustrate a plant nutrient provision system 10 comprising multiple separate quantities of a liquid and gas permeable soil-based medium 24 disposed within a nutrient-supply system 12, plant-support structures 14 supporting beds of plants 16 that include root systems 18, and first and second nutrient supply conduit systems 20 and 22 through which nutrients flow from the nutrient-supply structure 12 to the plants 16.

[0032] In some embodiments, the soil-based medium 24 may comprise enriched soil created by aging an optimal mixture of organic matter (e.g., soil, compost, etc.) and minerals in a bulk storage unit with means of aeration and water supply. In some embodiments, soil life breaks down and balances the soil mixture until it is suitable for growing plants. This bulk storage unit or container may be located on the ground level of a building or outdoors to reduce, eliminate, or nearly eliminate the soil load from the building structure. The soil-based medium may comprise multiple batches in separate containers which can be stacked at multiple levels to help increase aeration and reduce soil internal pressure. Once properly aged, the soil-based medium may be transferred from a bulk storage unit to the nutrient-supply system 12 through which a carrier liquid flows to entrain and transmit nutrients from the soil-based medium to the plants.

[0033] Soil especially suited for remote applications may be designed and sold or purchased to help enhance growing results.

[0034] Fluid including water, small soil particles, and root exudates may be returned from the remote plant beds to the nutrient-supply structure as a film traveling within drain pipes 28 that have vertical sections 30 and/or sufficiently sloped sections 32 to provide for gravity-driven flow. In some embodiments, fluid is kept as a film at the boundary of air (never submerged) and aerated along the way to one of two (or parallel) methods of soil contact within the nutrient supply structure. Parallel soil contact may help to increase the biodiversity of the system.

[0035] Soil Contact Type 1 – Sequential Soil Beds (Static, Gravity Drain)

[0036] In some embodiments, the nutrient supply system may comprise multiple soil beds 26 with screens at the bottom. The soil beds 26 may be stacked or otherwise arranged. In some embodiments, fluid from remote plant beds, alone or in conjunction with an external source of a fluid such as water, fills each of the soil beds starting with the closest to the source. External fluid may be supplied through a supply pipe, with flow being regulated by a control valve 36 and check valve 38. The supply pipe 34 may join a lower section 40 of drain pipe 28 to merge the flow of

external fluid with fluid flowing from the remote plant beds. The combined fluid may be sprayed, dripped and/or otherwise distributed into the soil beds. This may be accomplished in various ways. In one arrangement, multiple soil beds 26 may be positioned directly under drain pipe section 40 as shown in Fig. 3, with one or more adjustable orifices 42 distributing fluid directly onto or into each of the soil beds. In another arrangement, also shown in Fig. 3, the drain pipe section 40 may include an upper main section extending over upper soil beds, and multiple lower sections branching downward from the main upper section, then extending laterally over lower soil beds to distribute water and nutrients thereto. Each of the lower branches may have its flow controlled by an adjustable orifice 42 at its juncture with the main upper section, and may distribute fluid to the lower soil beds through one or more openings at or near its terminal which allow fluid to drip, spray or otherwise flow downward from the lower branches to the lower beds. As the soil-based medium 24 in each of the soil beds 26 approaches saturation and then becomes saturated, a respective adjustable flow control such as an adjustable orifice 42 associated with each of the soil beds 26 reduces then stops flow of fluid into the respective soil bed 26. In some embodiments, a wick 44 extending downward from the orifice 42 into the soil-based medium closes the adjustable orifice due to hydrostatic pressure. The next soil bed may then be filled until saturated, repeating the process for each bed. When the first bed is drained, hydrostatic pressure is released and the orifice opens, repeating the refilling process.

[0037] Means to effect airflow such as an air pump or fan 46 may be provided to increase airflow through the soil-based medium for more soil life activity and efficient use of space. In some embodiments, an air pump or fan may effect flow of air into the soil-based medium through a perforated diffuser 48 buried in the soil-based medium, or by forcing air into the soil-based medium through a mesh or screen 50 at the bottom of the soil bed. The air discharged from the soil-based medium may carry mist that results from water bubbling in the soil, and the system may be configured to carry this discharged air and removed moisture from the soil to the remote plant beds. To this end, each soil bed may be disposed within a sealed enclosure, and the air pump or fan 46 may force air through the soil-based medium and into a soil bed exhaust pipe 52 which carries the air and entrained moisture to merge with air flowing from the remote plant beds to the atomizer through an air return 54.

[0038] Soil Contact Type 2 – Rotating Soil Drum (Fluidized, Forced Draining)

[0039] In some embodiments, finished soil or soil-based medium is added to the interior of a rotating drum 82 with screened openings, mesh or other means to permit liquid to flow in, and

to permit liquid and small particles to flow out. The drum may rotate about a horizontal axis as shown in Fig. 3, or may be otherwise oriented. The drum may comprise a cylindrical wall 96 made of a screen or mesh material, or other perforated material. An access door 98 may be provided on one end to facilitate loading of soil and/or other solids into the drum interior. The drum may be rotated by a variable-speed drive 94. The drum may be operated with a slow tumbling motion powered via electric motor, wind, hydro or solar chimney power, or other means. It may also operate at higher speeds to accelerate water flow through the soil via centrifugal action. Fluid from the remote plant beds may be returned to the soil drum through a supply line 84, and external fluid such as water may be added through a supply pipe 86. As shown in Fig. 3, the external supply pipe may be positioned above the drum and may have an outlet 92 that sprays or otherwise distributes water downward onto the perforated cylindrical wall of the drum to continuously clean the screen while introducing external fluid into the drum interior. The return line 84 from the remote plant beds may enter the drum through an axial opening in an end wall opposite the door 98 so that fluid and entrained particulate matter can enter the drum interior directly, without passing through the screen. The mechanical and water flow action continuously helps to break down larger particles in the soil, while fluid and smaller particles will pass through openings at the bottom 100 of the drum into a collector 102 which drains through sloped pipe 104 into the atomizer. Fresh water is automatically added to the system as required through the control valve 88, which may be opened and closed in response to changes in the weight of the drum, impeller, and/or other system components. A check valve 90 may be provided to prevent back flow into the external fluid supply line, which automatically flushes the screens around the drum to keep them clear. As the soil is continuously broken down and consumed, additional finished soil from bulk storage is added manually or with an automatic hopper. The soil drum is a compact mechanical counterpart to the static soil beds in Type 1. It can also be utilized in extraterrestrial conditions with reduced gravity thanks to the centrifugal force.

[0040] Nozzle-free Atomizer

[0041] In some embodiments, after fluid has passed through the soil or medium, it continues to an atomization system or atomizer unit as a film, via pipes that may be sloped sufficiently to enable gravity-driven flow. In some embodiments, the atomization system does not utilize nozzles or ultrasonic elements due to potential clogging from particles. Instead, it may utilize a "continuous waterfall" that accelerates fluid as a film by using a rotating disc 58 wherein fluid clings to the disc temporarily, then is flung from the disc. The disc continuously lifts a film of fluid

from a small reservoir 64 at the bottom of the atomizer and causes it to continuously impact a splash screen. At the same time, moist air from the remote plant beds ("return air") is pulled into the atomizer through an inlet 70 via an air impeller 62 which acts as a blower fan to force air and particles through the splash screen 60, creating mist 66, i.e., particles of oxygenated fluid and nutrients suspended or entrained in the air flow. Mist is forced up to the remote plant beds via an insulated pipe 68. Flow of fluid within the atomizer is guided by a frustoconical top wall 80 and a baffle 72. The baffle extends across an upper portion of the outlet of the atomizer, and returns large particles to the reservoir. Falling particles within the pipe return back to the atomizer through the same pipe 68 for re-atomization. The falling particles may comprise condensate, agglomerated soil particles, or other particles. When these particles fall back down into the atomizer, they may be broken into smaller particles by the impeller, and the resulting smaller particles may then be sufficiently light to flow back upward to the remote plant beds. The bottom of the atomizer may be flexible and may be associated with a lever-controlled valve or other type of valve 78 that regulates flow of external water or fresh water into the atomizer, such that the weight of fluid in the reservoir exerts force on the lever to close the valve 78 to stop flow of external water into the atomizer as the weight reaches a predetermined limit. When the weight of water in the reservoir decreases below the limit, the valve may reopen and permit flow of external water into the atomizer. The atomizer may be a simple device employing only a single, unitary, one-piece rigid rotor comprising an impeller 62 and disc 58, with the impeller drawing in air and effecting airflow through the atomizer and p to the plant beds, while the disc throws off small particles to be entrained in air flowing through and out of the atomization system. The rotor is coupled to a drive mechanism 74 and may be driven or rotated by an electric motor and/or one or more renewable energy source (e.g., wind, hydro, solar chimney powered/).

[0042] Remote Plant Beds. In some embodiments, mist 66 flows from the atomizer to the remote plant beds via pipe 68. Pipe 68 may be provided with thermal protection, e.g., insulation and/or a reflective exterior if outdoors, to help control the temperature of the mist and thereby help to limit root temperature flux. Each of the plant support structures may house multiple plants for efficiency. Each structure may include a solid, laterally extending horizontal or sloped beam or platform with openings therein to receive plants. The plants may be supported in pots that have openings therein for root systems to extend through, with the pots being supported in the openings in the beam or platform. The pots may be netpots or other suitable pots. One type

of enclosure to help contain the root systems, as well as to help control humidity and/or temperature for the root systems is shown at 106.

[0043] One or more distribution pipes 108 may provide a mist or fine spray of water, minerals, and/or other nutrition for each row of plants. Each distribution pipe may have small holes or slots to discharge mist upward and laterally to coat the exposed roots with mist, and to coat the interior top surface or ceiling of the enclosure and to coat portions of the pots, from where liquid and entrained solids may drip onto and into the centers of the root masses where mist may not be able to reach directly from the distribution pipe in sufficient quantities. As shown in Fig. 4, a pair of distribution pipes may be provided, one on each side of a row of plants. The distribution pipes may be used together, or one at a time. Mist supply direction may be alternated to prevent uneven root growth and clogging of mist piping. Alternating the discharge side may help to manage the effects of hydrotropism (roots tendency to grow toward higher moisture levels). Copper mesh or other copper elements may also be utilized to control root growth away from pipes. Arrows 112 in Fig. 4 illustrate an example of a flow direction that may be used with pipe 108. Arrows 114 illustrate dripping of collected liquid and associated solids from the ceiling and pot.

[0044] An upper enclosure and/or plant support 116 may be provided above enclosure 106 to fully or partially enclose/support the stems, leaves and other portions of the plants above the root systems. Access doors 118 may be provided to facilitate access for initial introduction of plants into the system, as well as for harvesting fruits and vegetables, pruning, replacement of plants, etc.

[0045] The lower enclosures 106 may fully or partially contain the mist, i.e., limit or prevent dispersion of mist to the exterior of the system 10. The enclosures may have semi-permeable or air-permeable sidewalls to enable airflow for cooling and to facilitate horizontal root pruning.

[0046] The enclosures may include temperature-control features to reduce solar heat to the root zone, e.g., with reflective insulation, stand-off shading, or other means. Excess heat may be removed from the root zone to stabilize temperature by using evaporative cooling with natural draft chimneys or solar chimneys 109, and/or with air intake slots 120 at or near the bottom of an enclosure. Evaporative cooling may also be provided with semi-permeable enclosures open to the atmosphere which improve root pruning along sides of the enclosures. The semi permeable enclosures may be covered with water tight enclosures to allow periodic short term flooding of roots which allows for greater penetration in larger root masses than aeroponics

alone. To reduce maximum total weight, the flooding may be staged or cascaded into zones so only some of the enclosures are filled at one time.

[0047] The bottom of each enclosure may have a thin layer of buffer soil 132 or other medium to help maintain acceptable humidity and filter root particles from the system. A sloped drain pan may be provided below the beds to channel liquid and associated solids to the fluid return pipes or drain pipes 28. The roots may extend to the bottom of the enclosure. Automatic control of flow into the distribution pipe(s) may be provided through the use of a sensing wick 134 or other means to slow or stop flow through the distribution pipe after a volume or weight of carrier fluid and associated solids reaches a predetermined level. The automatic flow control may function to open a valve or aperture associated with a particular enclosure when lower hydrostatic pressure is sensed by a sensing tube or other apparatus, thereby helping to balance flow to multiple plant beds. An air return port 122 may be provided at or near the top of the enclosure 106 to permit saturated air to flow to the atomizer.

[0048] A second type of enclosure is shown at 124, for use in connection with a single large plant in a tower or pipe formfactor. The tower or pipe formfactor may allow greater pressure for the mist flow to penetrate better into root masses.

[0049] A third type of enclosure for use in connection with a vertical formfactor is shown at 126. The enclosure 126 may allow multiple small plants to be grown in the same floor area by arranging the plants in vertical rows in a pipe or tower formfactor.

[0050] In some embodiments, the plant nutrition system may include many separate enclosures connected in parallel or in series. The system may be configured to provide for simultaneous or sequential supply of water and nutrients to various enclosures and their associated plants.

[0051] The second and third types of enclosures may be used with the features described above with respect to the first enclosure, including automated flow control on inlet piping, venting of saturated air through a return port 122 at or near the top of each enclosure, use of copper mesh 128 to automatically prune roots and/or limit root growth, and use of a sloped floor drain to facilitate flow of liquid and associated solids downward to the atomizer. Additional features include an optional air pump 136 to oxygenate and prune roots from the bottom, and an optional accumulator tank system 138 including a pump and a supply line to collect and effect flow of carrier liquid and nutrients from the bottom of an enclosure to the center of an associated pot to effect greater penetration of the root mass, which may be particularly useful

for larger plants with larger root masses. A siphon 140 may be provided to effect draining of the enclosure automatically when the fluid level in the enclosure reaches a certain level. This may be useful in conjunction with a system that periodically floods an entire root mass for a short period of time to allow greater penetration into the center, and cleansing of the semi-permeable material. A semipermeable enclosure 142 may be provided inside a water-tight enclosure to allow an air gap around a root mass and effect automatic root pruning. Siphons 140 may be connected to multiple beds or groups of beds at different elevations to allow cascading, illustrated at Fig. 5, such that flooding occurs automatically and sequentially, to reduce the weight of the system during flooding operations.

[0052] With respect to automated flow control, a sequence of aperture positions ranging from almost fully open to almost fully closed is shown at 130.

[0053] Weight of the remote plant beds and associated components may be relatively low where nearly all the soil used to provide nutrients remains at grade level or other locations where it does not add weight to the remote plant beds, and where only the small particles are brought to the enclosures while suspended in moist air and coating the roots. Excess fluid and soil particles may fall from root masses to a small layer of buffer soil at the bottom of the bed. In some embodiments, the depth of the buffer layer will be the minimum depth, or close to the minimum depth, required to stabilize bed moisture. The depth may vary depending on plants grown, local climate and construction. In various embodiments, the depth may be, e.g., about 3 in., about 6 in., or from 0 to 4 in., or from 0 to 6 in. Soil life including worms can thrive in the remote plant beds and utilize substantially the same soil particles as they would in traditional soil. Roots can utilize enzymes and soil life to break down the particles surrounding them as they normally would in soil. The greater ratio of surface area to mass for smaller particles and increased amount of oxygen may result in a faster conversion of plant nutrients within the rootzone as compared with traditional soil. A mesh bottom may be provided for the enclosures to allow for airflow and automatic pruning of roots. Pruning prevents root binding and encourages root growth toward the top of the enclosure. Enclosures are filled with mist from the top via sloped pipe and openings with hydrostatic controlled lining (with wick down throughout soil bed). Excess fluid from the soil bed is then drained as a film via sufficiently sloped pipes and returned down to grade to the soil contact section. Moist air (without mist particles by using enlarged elbow down to allow mist to settle (air velocity reduced to less than

0.5-1.0 fps) is drawn from the remote plant beds and brought down to ground level to the atomizer section via reflective insulated pipe.

[0054] When water is called for by the system (via atomizer), it is sprayed from the bottom to continuously clear the plant bed screens (or manual cleaning with hand sprayers may be employed).

[0055] Fluid Return

[0056] Fluid from the plant beds may be returned to the atomizer to repeat the cycle. An optional small accumulator tank with pump and overflow pipe at the fluid return may be provided. The pump will discharge fluid directly into the center of plant net pots so the fluid can drop down via gravity to the center of the root mass. This allows more efficient fluid exchange to the center of large root masses that are poorly penetrated by aeroponics alone.

[0057] Additional Features

[0058] In some embodiments, the systems described herein may offer one or more of the following features:

[0059] 1. Growth in a 100% soil-based medium with the additional benefits of being:

[0060] - lighter to grow on top of areas not suitable for soil

[0061] - suitable for placement on roofs of buildings or other structures

[0062] - suitable for placement indoors on building floors

[0063] - suitable for use in or above areas not suitable for growing, e.g., areas having contaminated soil, without needing to entirely top fill with new soil

[0064] - suitable for use as temporary "popup gardens" with apparatus that can be set up at the beginning of a growing season, and put away and stored compactly at the end of a growing season

[0065] - stageable for growing where bringing in all soil at once is not an option

[0066] 2. Only a small amount of soil as required for the plants' daily needs is required to be on site at one time as long as the soil is replenished often enough. For example, it may be possible to grow soil-based crops almost anywhere by bringing in relatively small amounts of soil at any one time instead of needing to bring in a much larger mass of soil all at once.

[0067] The plants may rely entirely on natural sunlight, artificial light sources, combinations thereof, etc. The overall system described herein and/or individual components thereof may employ a windmill or wind turbine 144, a solar chimney 146, solar panels, conventional electric power, or other sources of power to drive pumps, fans, lighting systems and/or other components.

[0068] Conclusion

[0069] The systems contemplated herein are not limited to the examples described herein, and are not limited to including the features described herein. It is contemplated that the systems described herein may use any or all of the features described herein to the extent reasonably possible, to provide improved methods and apparatus for providing nutrients to plants.

Claims

1. A method of providing one or more nutrients to a plant that has a root system, the method comprising:
 - a. providing a liquid and gas permeable soil-based medium comprising particulate organic matter, minerals, liquid, and organisms,
 - b. providing a structure supporting the plant and maintaining an environment suitable for root growth such that within the structure the root system is exposed and accessible, and
 - c. effecting intermittent flow of a carrier liquid through the soil-based medium to maintain gas permeability suitable for soil organisms to cause entrainment of a portion of the soil-based medium in the carrier liquid, then into contact with the root system in a manner that provides a film of carrier liquid on at least part of the root system and effects transfer of dissolved nutrients and particulate matter from the soil-based medium to the root system.
2. The method of claim 1 wherein the soil-based medium comprises organic soil at or near grade level and wherein the carrier liquid comprises water.
3. The method of claim 2 wherein the structure comprises:
 - a. a roof-mounted frame placed in a location can expose portions of the plant to natural sunlight and
 - b. a lightweight, aerated, humidity-controlled enclosure around the root system.
4. The method of claim 3 wherein effecting flow of the carrier liquid comprises filtering the carrier liquid to retain certain particles, pumping the carrier liquid to the enclosure while maintaining the flow of carrier liquid as a film bounded by air for gas exchange, then spraying with sufficiently low velocity to prevent root damage at least a portion of the carrier liquid and entrained particulate matter onto the root system.
5. The method of claim 4 wherein spraying comprises effecting flow of the carrier liquid and entrained particulate matter from a conduit onto an intermediate surface such that droplets of the carrier liquid are caused to travel from the intermediate surface to the root system, wherein the film of carrier liquid on the root system enables absorption of water and nutrients by the root system and wherein the film is bounded by air.

6. The method of claim 5 wherein the intermediate surface comprises a surface on a spinning disc wherein the disc is powered at least partially by one or more of an electric motor, renewable energy, wind energy, hydro, or a solar chimney.

7. The method of claim 6 further comprising providing a return system that collects excess carrier liquid, particulate matter and root exudates, aerates the excess carrier liquid, and returns the excess carrier liquid, particulate matter and root exudates to the soil-based medium. The addition of root exudates to the soil-based medium assists in decomposition, moisture retention and all the natural nutrient conversion processes typically found in soil. These nutrient conversion processes are modulated by the root exudates to control the chelation, inhibition and retention of nutrients for optimal absorption as demanded by the plant in real-time.

8. The method of claim 7 wherein the soil-based medium and plant root zones include organic soil life such as actinomycetes, algae, archaea, bacteria, fungi, protozoa, and/or larger soil fauna such as arthropods, earthworms and nematodes which assist with decomposition, aeration nitrogen fixation as well as further assisting the natural soil nutrient conversion processes taking place therein.

9. The method of claim 8 wherein effecting flow of the carrier liquid can be conducted continuously and without interruption for an indefinite number of days without discarding or "flushing" the carrier fluid as typically done in hydroponics/aeroponics.

10. The method of claim 9 wherein the plant produces one or more edible products or one of more medicinal products with other methods of consumption like topical, inhalation or suppository.

11. The method of claim 10 further comprising holding the soil-based medium in stacked soil beds wherein effecting flow of carrier liquid includes effecting flow sequentially into and out of the stacked soil beds to maintain soil porosity for aeration and flow.

12. The method of claim 10 further comprising creating a soil-based medium by aging, aerating, and supplying water to a mixture of organic matter and minerals in a bulk storage unit.

13. The method of claim 10 wherein effecting flow of carrier liquid through the soil-based medium comprises effecting flow of water through a rotating drum containing the soil-based medium.
14. The method of claim 10 further comprising maintaining a buffer layer of moist soil in the enclosure, and maintaining soil life in the enclosure.
15. The method of claim 10 further comprising using air as a second carrier by effecting flow of air through the soil-based medium, and using the air to carry moisture from the soil-based medium to the remote plant beds.
16. The method of claim 10 wherein the enclosure is semi-permeable and open to the atmosphere, and the enclosure effects evaporative cooling and root pruning, and the enclosure has a vertical tower or pipe formfactor, and the enclosure is covered with a water-tight enclosure to allow periodic short-term flooding of roots.
17. The method of claim 10 wherein mist supply direction is alternated, and wherein copper elements are used to control root growth.
18. The method of claim 1 further comprising using an atomizer to create a spray for application to the root system, collecting drainage fluid from the root system, and returning at least a portion of the drainage to the atomizer to repeat the cycle.
19. The method of claim 18 further comprising collecting a portion of the drainage fluid from the root system in an accumulator tank, and pumping drainage fluid from the accumulator tank upward to a central region of the root system.
20. A plant nutrient provision system comprising:
 - a. a liquid and gas permeable soil-based medium;
 - b. a structure supporting a plant that includes a root system, the structure having an interior and maintaining a controlled environment within the interior and enclosing the root system therein so that within the structure the root system is exposed and accessible, the soil-based medium being outside of the structure and separate therefrom; and

c. a fluid flow system that effects flow of a carrier liquid through the soil-based medium to cause entrainment of a portion of the soil-based medium in the carrier liquid, then into contact with the root system in a manner that provides a film of carrier liquid on at least part of the root system and effects transfer of dissolved nutrients and particulate matter from the soil-based medium to the root system;
wherein the structure comprises a frame capable of being supported on a residential building in a location that can expose portions of the plant to natural sunlight.

FIG. 1

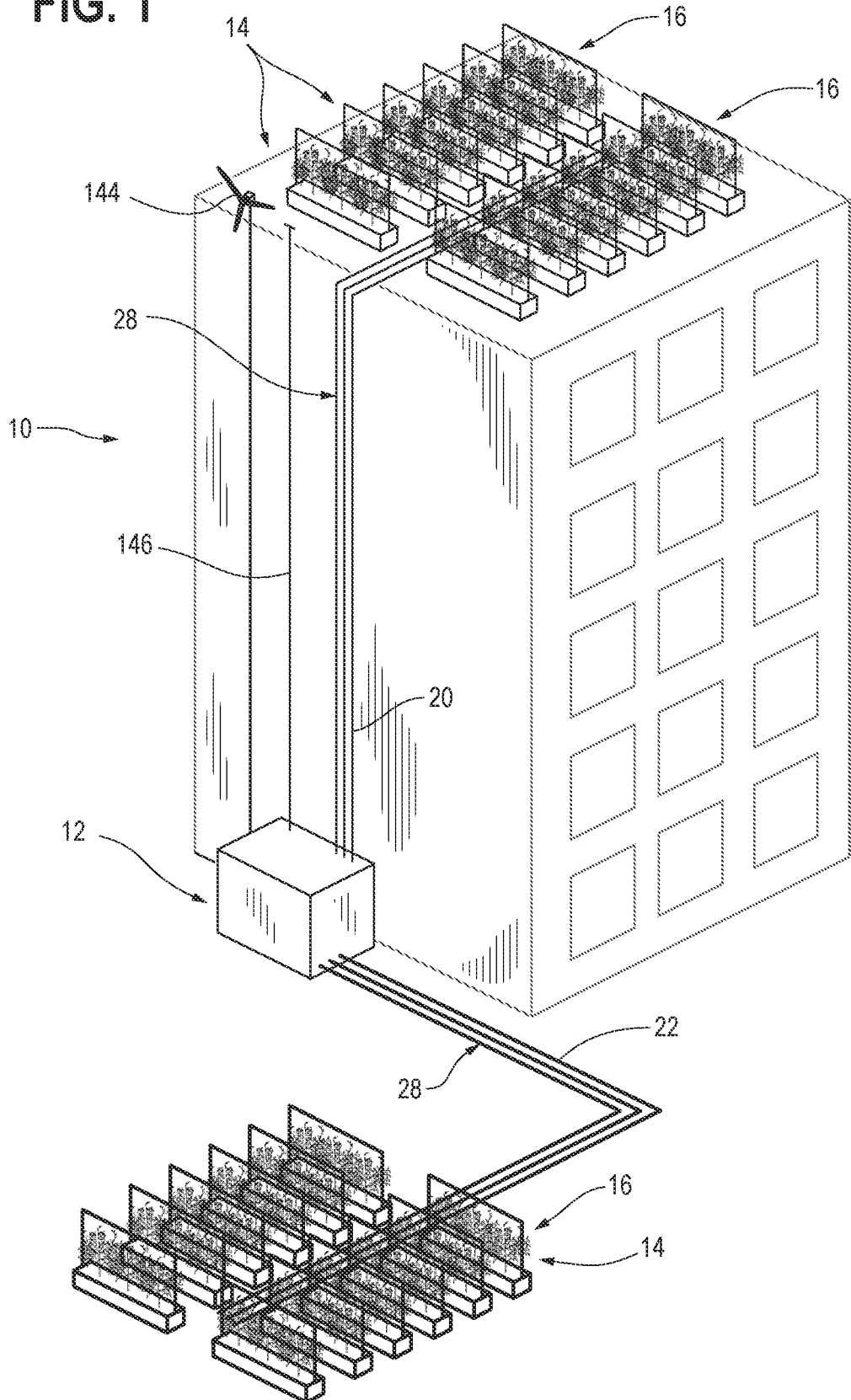


FIG. 2

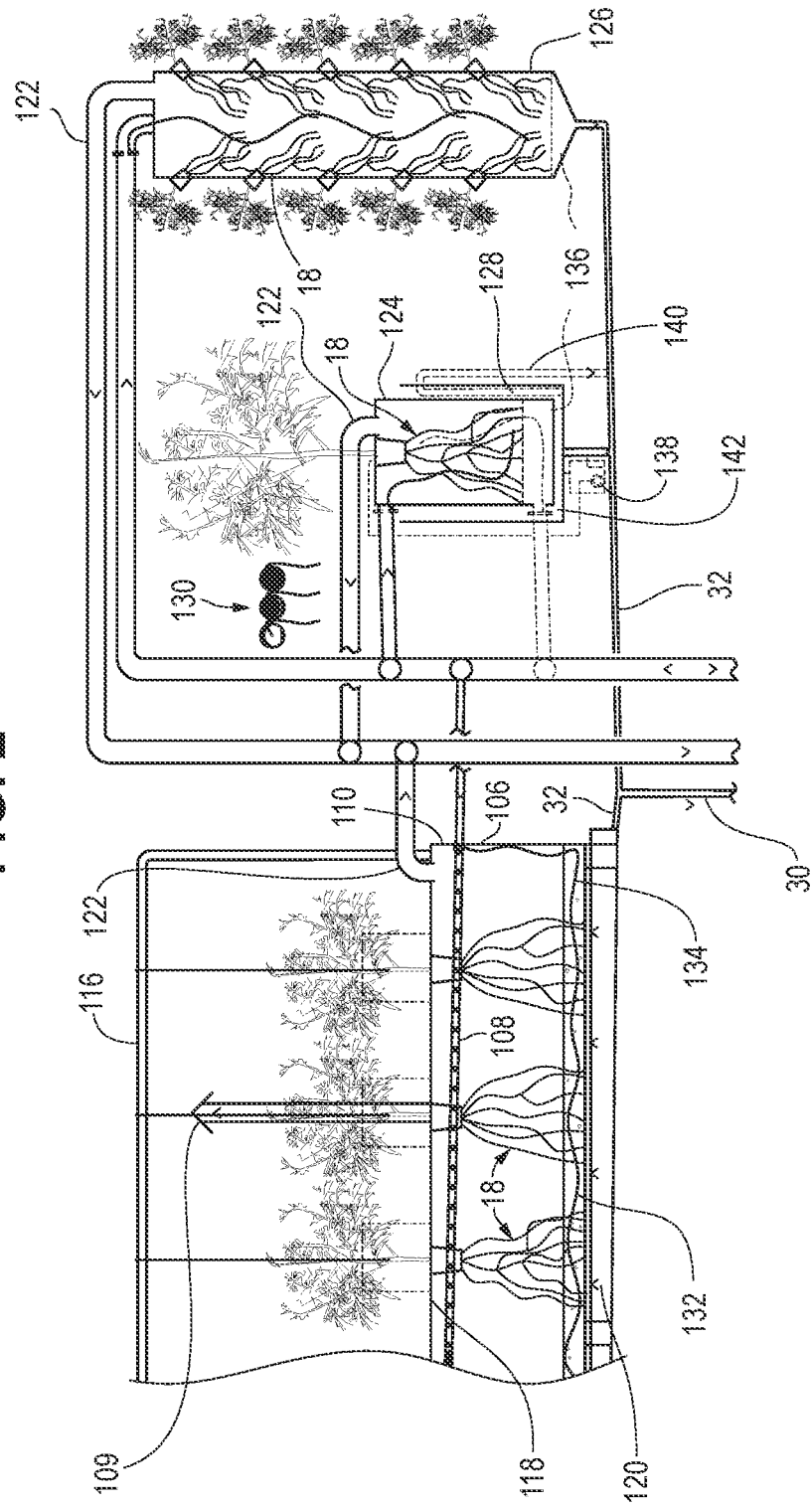


FIG. 3

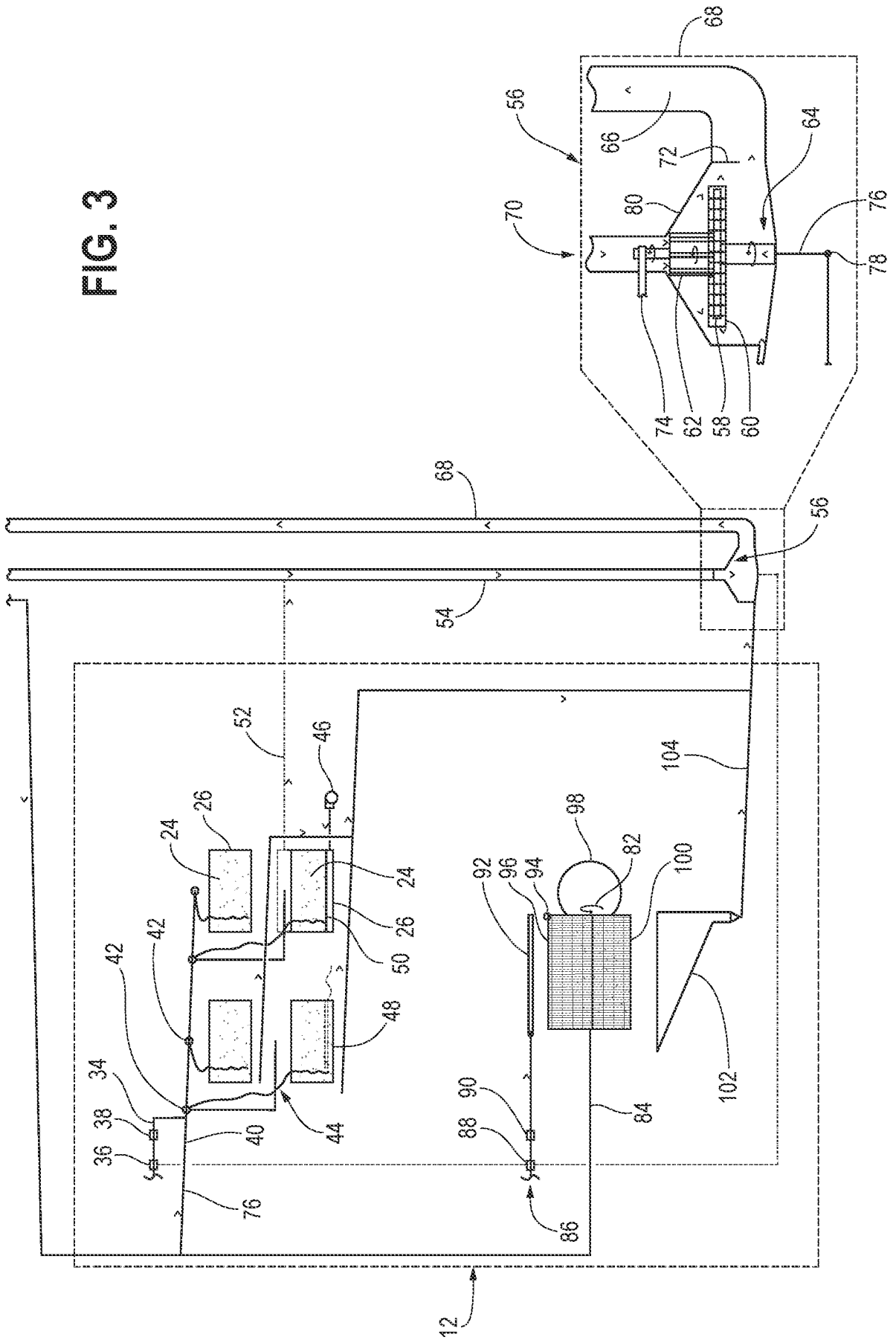


FIG. 4

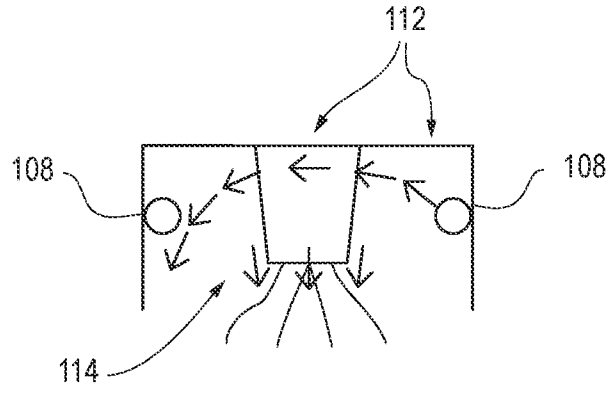


FIG. 5

