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(54) Automatic liquid handling and temperature control for a spa

(57) A spa includes a housing forming a vessel, an opening formed in the vessel, a valve fluidly coupled to the opening, a liquid sensor configured to measure an amount of liquid in the vessel, and a controller operatively connected to the valve and the liquid sensor. The controller operates the valve to drain liquid the vessel through the opening, and operates the valve to fill the vessel with liquid from a liquid source when a predetermined amount of liquid has drained from the vessel.

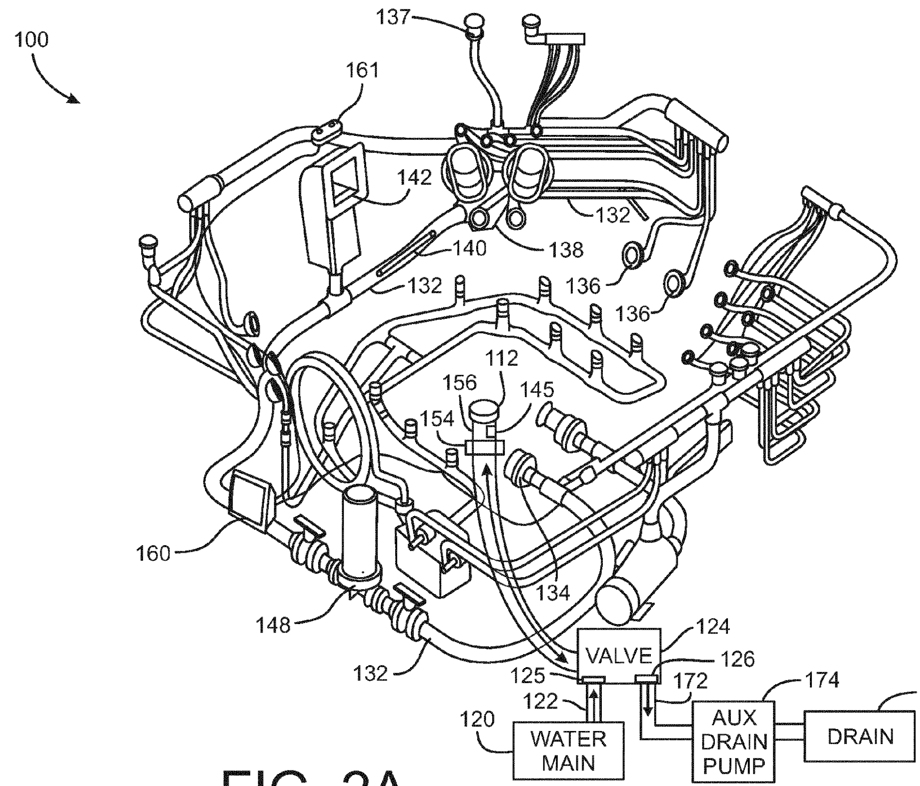

FIG. 2A

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Description

Technical Field

[0001] This application relates generally to spas that hold water or another liquid, and, in particular, to control of filling, draining, and heating liquid in spas.

Background

[0002] Spas, which are also referred to as hot tubs, are popular recreational and therapeutic devices used in both indoor and outdoor environments. A typical spa includes a shell holding water with one or more pressurized jets that spray the water, and optionally air bubbles, into the shell. Spas of various shapes and sizes can hold one or more occupants in the shell, and the jets of water and air provide relaxation and therapeutic benefits to the occupants. Most spas include a water heater that heats the water in the shell to an elevated temperature.

[0003] While spas can provide relaxation and therapeutic benefits, the maintenance and operation of a spa requires manual labor and consumes large quantities of electrical power, water, and treatment chemicals. Regular spa maintenance is a time consuming process. If a spa is not properly maintained, bacteria, fungi, and/or algae may grow in the spa and require additional cleaning and repair of the spa. A spa typically requires manual maintenance to treat the water in the spa to keep the spa in working order, even when the spa is used infrequently. A manual maintenance process often drains all of the water and chemicals from the spa to flush contaminants from the spa, resulting in high consumption of water and treatment chemicals. Additionally, most spas use one or more electric heaters, such as Calrod® heating elements, to heat water. To heat water held in the shell, the spa pumps the water out of the shell, heats the pumped water with the heater, and pumps the heated water back into the shell. The heating process consumes energy in the forms of natural gas or electrical power to heat the water, and to pump the water past the heater. Consequently, spas that reduce the requirement for manual maintenance and that operate with reduced energy usage and water consumption would be beneficial.

Summary

[0004] In one embodiment, a spa has been developed. The spa includes a housing forming a vessel, an opening formed in the vessel, a valve fluidly coupled to the opening, a liquid flow sensor configured to measure liquid flow through the opening in the vessel, and a controller operatively connected to the valve and the liquid flow sensor. The controller is configured to operate the valve to place the opening in fluid communication with a drain to enable liquid within the vessel to drain from the vessel, operate the valve to place the opening in fluid communication with a water source to enable liquid to enter the vessel through the opening with reference to a signal from the liquid flow sensor, that indicates a predetermined volume of liquid has drained from the vessel, and operate the valve to remove the opening from fluid communication with the drain and the water source in response to the controller identifying that the predetermined volume of liquid has entered the vessel.

[0005] In another embodiment, a spa has been developed. The spa includes a housing forming a vessel, an opening formed in the vessel, a valve fluidly coupled to the opening, a liquid level sensor positioned proximate to the opening and configured to generate a first signal in response to a level of liquid in the vessel being below a first predetermined level and a second signal in response to a level of liquid in the vessel being above a second predetermined level, the second predetermined level being greater than the first predetermined level, and a controller operatively connected to the valve and the liquid level sensor. The controller is configured to operate the valve to place the opening in fluid communication with a drain enable liquid within the vessel to drain from the vessel, operate the valve to place the opening in fluid communication with a water source to enable liquid to enter the vessel through the opening in response to the first signal from the liquid level sensor, and operate the valve to remove the opening from fluid communication with the drain and the water source in response to the second signal from the liquid level sensor.

[0006] In another embodiment, a liquid management device for a spa has been developed. The liquid management device includes a housing, an inlet fluid coupling formed in the housing and configured to be fluidly coupled to a liquid source, an outlet fluid coupling formed in the housing and configured to be fluidly coupled to a drain, a bidirectional fluid coupling formed in the housing and configured to be fluidly coupled to a tub in a spa, a valve located in the housing and fluidly connected to the inlet fluid coupling, the outlet fluid coupling, and the bidirectional fluid coupling, and a controller operatively connected to the valve. The controller is configured to operate the valve to place the inlet fluid coupling in fluid communication with the bidirectional fluid coupling to enable liquid from the liquid source to flow into the tub, operate the valve to place the outlet fluid coupling in fluid communication with the bidirectional fluid coupling to enable liquid from the tub to flow to the drain, and operate the valve to remove both the inlet fluid coupling and outlet fluid coupling from fluid communication with the bidirectional fluid coupling to prevent liquid from flowing through the valve.

[0007] In another embodiment, a spa has been developed. The spa includes a housing forming a vessel, a first opening formed in the vessel, a second opening formed in the vessel and fluidly coupled to the first opening through a fluid conduit, a pump fluidly coupled to the fluid conduit, a valve fluidly coupled to the first opening and the second opening through the fluid conduit, and a controller operatively connected to the valve and the pump. The controller is configured to operate the valve to place the first opening in fluid communication with a drain and to operate the pump to pump liquid from the vessel through the first opening to the drain, operate the valve to place the second opening in fluid communication with a water source to enable liquid to enter the vessel through the second opening, and operate the valve to remove the first opening from fluid communication with the drain and the second opening from fluid communication with the water source and to operate the pump to pump liquid from the vessel through the first opening through the conduit and into the vessel through the second opening.

Brief Description of the Figures

[0008] The foregoing aspects and other features of a spa are described in connection with the accompanying drawings.

[0009] FIG. 1 is a perspective view of a spa including a housing.

[0010] FIG. 2A is a perspective view of components in the spa of FIG. 1 with the housing omitted.

[0011] FIG. 2B is a perspective view of another configuration for components in the spa of FIG. 1 with the housing omitted.

[0012] FIG. 3 is a perspective view of an infrared heater in a fluid conduit.

[0013] FIG. 4 is a perspective view of an infrared heater engaging an exterior of a fluid conduit.

[0014] FIG. 5 is a block diagram of a process for operating a spa.

[0015] FIG. 6A is a schematic diagram of a liquid management device for a spa.

[0016] FIG. 6B is another schematic diagram of the liquid management device of FIG. 6A.

[0017] FIG. 6C is another schematic diagram of the liquid management device of FIG. 6A and FIG. 6B.

[0018] FIG. 7 is a prior art diagram of an absorption spectrum of water.

Detailed Description

[0019] For a general understanding of the environment for the system and method disclosed herein as well as the details for the system and method, reference is made to the drawings. In the drawings, like reference numerals have been used throughout to designate like elements. As used herein, the term "spa" refers to a vessel that holds a volume of liquid, such as water, which is heated and circulated through the vessel. One or more occupants enter the vessel and soak in the liquid for relaxation and therapeutic purposes. In a common embodiment, the spa holds liquid water, although a variety of additives including chlorine and other sanitizing chemicals, and therapeutic chemicals are often added to the water in the spa.

[0020] FIG. 1, FIG. 2A and FIG. 2B depict a spa 100. FIG. 1 depicts an exterior of the spa 100 including a housing 104. FIG. 2A and FIG. 2B depict additional components in the spa 100 with the housing 104 omitted. In FIG. 1, the housing 104 defines a vessel 106 with combination drain/fill port 112, circulation jet outlets 136, and a skimmer 142. The spa 100 includes infrared heater panels 116A and 116B, controller 160, treatment unit 148, and a liquid recirculation conduit 132, all of which are external to the vessel 106. In FIG. 1, the housing 104 is formed from a single-piece or "unibody" fiberglass shell, although the housing can be formed with other materials and alternative housings are formed with multiple pieces. A finished spa can include an external cabinet or skirt (omitted for clarity) arranged around the periphery of the housing 104 to hide the exterior of the housing 104 and various other components of the spa. Additionally, the housing 104 and fluid conduits in the spa can be covered with insulation to retain heat within the spa 100.

[0021] The housing 104 is formed with an interior shape that defines multiple side-walls 110 and a floor 113. In the example of FIG. 1, the housing 104 also forms a seat 115. While FIG. 1 depicts one exemplary housing design, alternative spa housings include a wide range of shapes, sizes, and configurations. The spa 100 includes infrared heating panels 116A and 116B. Both of the heating panels 116A and 116B are positioned in contact with the housing 104 on the opposite side of the vessel 106 to enable the heating panels 116A and 116B to radiate heat through the fiberglass shell while remaining isolated from contact with the fluid in the vessel 106. The infrared heating panel 116A curves to conform to the contours of the housing 104, and the infrared heater 116B is located in the seat 115. In another embodiment, one or more rectangular infrared heater panels engage the sides of the housing 104. In still another embodiment, an inductive infrared heater includes an inductor coil that is mounted on an external wall of the vessel and a passive inductive element that is mounted an interior wall 110 of the vessel 106. An electrical current applied to the inductive coil induces a current in the passive element that generates infrared energy to heat liquid in the vessel 106. When activated with an electrical current, the infrared heaters 116A and 116B emit infrared energy to heat liquid in the vessel 106. The infrared heaters 116A and 116B enable the spa 100 to heat liquid in the vessel 106 efficiently without requiring circulation of liquid from the vessel 106.

[0022] FIG. 2A depicts the spa 100 with the housing 104 omitted to reveal additional components in the spa. The drain/fill port 112 is an opening formed preferably located near the bottom of the shell of the vessel 106 that is fluidly coupled to a three-way valve 124 through a conduit 156. The three-way valve 124 can place the conduit 156 and drain/fill port 112 in fluid communication with either a utility water main 120, a drain 170, or the valve 124 can remove the fluid conduit 156 from fluid communication with both the water main 120 and drain 170. In the example of the spa 100, the fluid conduit 156 includes one or more sections of a pipe or hose such as polyvinyl chloride (PVC) pipe, rubber hose or copper pipe. Flexible conduits 122 and 172, such as a rubber hoses, can connect the valve 124 to the water main 120 and drain 170, respectively. The water main 120 is typically a residential water main or well that provides water to residential premises, but any source of pressurized liquid at a suitable pressure level can be used with the valve 124 and fluid conduit 156. In some embodiments, additional chemicals are added to the water as the water flows through the inlet conduit 122. The drain conduit 172 leads to a drain 170, such as a sump or other location where liquid drained from the spa can flow under the force of gravity.

[0023] In the example of the spa 100, the valve 124 is a multi-solenoid valve that includes a first solenoid 125 that opens and closes a stopper between the valve 124 and the fluid conduit 122 leading to the water main 120, and a second solenoid 126 that opens and closes another stopper between the valve 124 and the fluid conduit 172 leading to the drain 170. Both solenoids 125 and 126 remain closed to hold liquid in the vessel 106. The first solenoid 125 is opened to enable water from the water main 120 to flow into the vessel 106. The second solenoid 126 is opened to enable liquid in the vessel 106 to flow through the conduit 156 and to the drain 170 under a force of gravity. The solenoids in the valve 124 are operatively connected to the controller 160 and the controller 160 opens and closes the stoppers with the solenoids to control the level of liquid in the vessel 106. While valve 124 is a solenoid valve, other three-way valves including ball valves can be used as well.

[0024] In the configuration of FIG. 2A, an optional auxiliary drain pump 174 is fluidly connected to the valve 124 and the drain 170. The auxiliary drain pump 174 is activated when the valve 124 opens the solenoid 126 to drain the vessel 106. In the spa 100, the controller 160 activates and deactivates the auxiliary drain pump 174. The auxiliary drain pump 174 expedites the draining process for the vessel 106 compared to draining the vessel 106 under only the force of gravity.

[0025] In FIG. 2A, a pump 138 and recirculation fluid conduit 132 are configured to draw liquid from the vessel 106 through a suction inlet 134 and pump the liquid back into the vessel 106 through recirculation outlets 136. In addition to water that is drawn through the suction inlet 134, a skimmer 142 collects liquid near the top of the housing 104 and the liquid enters the recirculation conduit 132. The pump 138 optionally receives air from the environment around the spa 100 through an air inlet 137 and injects the air into the recirculation fluid conduit 132 after the liquid passes a treatment unit 148 and heater 140. Liquid in the recirculation conduit 132 passes through a treatment unit 148. The treatment unit 148 in the FIG. 2A includes an optional ozone generator that introduces ozone (O_3) into the liquid or optional ultraviolet (UV) light to sanitize the fluid during recirculation. In alternative embodiments, the treatment unit 148 includes various filters and can introduce chlorine or other treatment chemicals into the recirculation fluid conduit 132. The heater 140 is an infrared heater that is configured to heat liquid in the recirculation conduit 132 prior to the liquid being returned to the vessel 106. The infrared heater 140 can be a cylindrical quartz heater, ceramic heater, or any other infrared heater that is suitable for use with the spa 100. The infrared heater 140 can be selectively activated to generate heat when the pump 138 recirculates liquid from the vessel 106. In some configurations, the infrared heater 140 also heats the liquid in the recirculation conduit 132 to kill bacteria, fungi, algae, and other microorganisms in the liquid. The spa 100 recirculates the liquid to maintain an elevated temperature of the liquid in the vessel 106, disinfect the liquid, provide pressurized jets of water, and optionally a mixture of water and air through the outlets 136 to the occupants in the vessel 106.

[0026] FIG. 3 and FIG. 4 depict two exemplary configurations of an infrared heater with a fluid conduit, such as the infrared heater 140 in the spa 100. In FIG. 3, an infrared heater 408 is located inside of the lumen 410 of a conduit 404. Electrical current passes through the infrared heater 408 and heats liquid in the lumen 410. In FIG. 4, an infrared heater 412 engages an outer circumference of the fluid conduit 404. The infrared heater 412 radiates heat inward through the conduit wall 404 to heat liquid in the lumen 410. In an alternative embodiment, the heater 412 forms a portion of the wall of the conduit 404 so that the heater 412 directly radiates infrared energy into the liquid in the lumen 410.

[0027] The heaters 408 and 412 emit infrared energy into the liquid to heat the liquid in an efficient manner. In a typical embodiment where a substantial portion of the liquid is water, the heaters 408 and 412 emit a large proportion of the infrared energy near a wavelength of 3 μm. As depicted in a prior art absorption spectrum graph in FIG. 7, water has an absorption peak around wavelengths of 3 μm depicted at reference number 904. Thus, the water in the lumen 410 absorbs the infrared energy from the heaters 408 and 412 efficiently. The infrared heater panels 116A and 116B also emit infrared radiation in the 3 μm wavelength range to heat water in the vessel 106 efficiently.

[0028] Referring again to FIG. 2A, liquid is added to the vessel 106 through the drain/fill port 112 and re-circulated in the vessel 106 through the recirculation conduit 132. During a cleaning or maintenance operation, liquid drains from the vessel 106 through the drain/fill port112, which is a fluid outlet through the housing 104 that is coupled to a conduit 156. An optional flow sensor 154 generates signals in response to a flow of water or other fluid through the drain/fill port 112 and conduit 156. As depicted in FIG. 1, the drain/fill port112 is located near the floor 113 of the housing 104 to enable liquid in the vessel 106 to flow through the drain/fill port 112 under a force of gravity.

[0029] Referring again to FIG. 2A, the spa 100 includes a level sensor 145 to monitor a level of liquid in the vessel 106 and a flow sensor 154 to monitor a flow of liquid into or out of the vessel 106 through the fluid conduit 156. In the spa 100, both the level sensor 145 and the flow sensor 154 are located in the fluid conduit 156 proximate to the drain/fill port 112. Optionally the level sensor 145 may be fluidly connected to the walls 110 (ref. Fig. 1) of the shell near the floor or bottom of the shell. The control 160 is operatively connected to the flow sensor 154 to monitor a volume of liquid that flows into or out of the vessel 106, and the level sensor 145 to monitor an amount of liquid in the vessel 106. While FIG. 2A depicts the spa 100 as having both a flow sensor 154 and level sensor 145, an alternative configuration can include either the flow sensor 154 or the level sensor 145.

[0030] The liquid level sensor 145 generates signals based on the level of liquid in the vessel 106. In one configuration, the liquid level sensor is a pressure sensor 145 that is located in the fluid conduit 156 proximate to the floor 113 of the vessel 106. The pressure sensor 145 generates pressure signals with reference to a continuously changing level of fluid in the vessel 106. As is known in the art, the level of pressure in the fluid conduit 156 at the base of the vessel 106 increases as the level of water in the vessel 106 increases. In one embodiment, the pressure sensor includes a sealed chamber filled with air at a predetermined pressure and a pressure transducer. As liquid fills the vessel 106, the liquid exerts pressure the sealed chamber and the pressure of air in the chamber increases. The pressure transducer generates a signal corresponding to the increased air pressure. The controller 160 receives signals generated by the level sensor 145 to identify the level of liquid in the vessel 106. While the level sensor 145 is described as a pressure sensor for illustrative purposes, the spa 100 can include any suitable level sensor that identifies a plurality of levels of liquid in the vessel 106.

[0031] The flow sensor 154 identifies both a volume of liquid that flows through the conduit 156 and a direction of the flow of liquid. Since the conduit 156 enables liquid to flow into the vessel 106 and out of the vessel 106, the flow sensor 154 enables the controller 160 to identify the volume of liquid that is used to fill the vessel 106 and the volume of liquid that is drained from the vessel 106.

[0032] Spa 100 includes a controller 160 that is operatively connected to various components in the spa. In the examples of FIG. 1, FIG. 2A, and FIG. 2B, the controller 160 is operatively connected to the solenoids 125 and 126 in the valve 124, infrared heaters 116A, 116B, and 140, pump 138, flow sensors 154, and a pressure sensor 145. The controller 160 can be implemented with general or specialized programmable processors that execute programmed instructions. The instructions and data required to perform the programmed functions are stored in memory associated with the processors or controllers. The processors, their memories, and interface circuitry configure the controller to perform the functions described herein for the spa 100. Various embodiments of the controller 160 include programmable microcontrollers, microprocessors, field programmable gate arrays (FPGAs), and application specific integrated circuits (ASICs). Each of the circuits in the controller 160 can be implemented with a separate processor or multiple circuits can be implemented on the same processor. Alternatively, the circuits can be implemented with discrete components or circuits provided in VLSI circuits.

[0033] The memory in the controller 160 optionally stores configuration parameters entered by a user via a user interface device 161 and data corresponding to the operating history of the spa 100. The user interface device 161 displays data generated by the controller 160 and generates signals to operate the controller 160 and spa 100. In one embodiment, the user interface device includes a visual display screen, such as an LCD display, to provide information regarding the operation of the spa 100 to a user. The user interface device 161 also displays options for commands and operational settings, and includes an input device, such as buttons or a touchscreen interface, to enable a user to enter commands and update settings for the controller 160. The user interface device 161 is integrated into the housing 104 in the spa 100, but the user interface device can also be a remote control that is detached from the spa 100 in another embodiment. In another remote control embodiment, the controller 160 includes a wireless network device, such as a Bluetooth or wireless local area network (WLAN) transceiver using one of the 802.11 family of protocols. The operator uses a software application program in a mobile electronic device, such as a smartphone or tablet, to send wireless data messages to the controller 160 for setting a schedule of drain and refill operations in the vessel 106, and to control other operations in the spa 100.

[0034] FIG. 2B depicts another configuration for the spa 100. In FIG. 2B, the spa 100 the fluid conduit 132 includes a diverter valve 139 that is fluidly coupled to the three-way valve 124. The diverter valve 139 enables liquid to flow through from the pump 138 to the circulation jet outlets 136 in a first configuration, or places the outlet of the pump 138 in fluid communication with the three-way valve 124 through the fluid conduit 132 in a second configuration. The controller 160 is operatively connected to the diverter valve 139 to switch the diverter valve 139 between the first and second configurations. Another embodiment omits the diverter valve 139 and includes a T-junction in the fluid conduit 132 between the pump 138, the three-way valve 124, and the circulation jet outlets 136.

[0035] In the configuration of FIG. 2B, the spa 100 drains liquid in the vessel through the suction inlet 134 and fills liquid in the vessel through the circulation jet outlets 136. During a drain operation, the diverter valve 139 diverts the flow of liquid from the pump 138 to the three-way valve 124. The solenoid 126 in the three-way valve 124 opens to enable liquid to flow to the drain 170. The pump 138 urges liquid from the vessel 106 through the suction inlet 134 and through the diverter valve 139 to drain the vessel 106. During a fill operation, the diverter valve 139 places the valve 124 in fluid communication with the circulation jet outlets 136. The solenoid 125 in the three-way valve 124 opens to enable liquid from the water main 120 to flow into the vessel 106 through the circulation jet outlets 136. The pump 138 is deactivated during the fill process. During a circulation operation, the diverter valve 139 places the pump 138 in fluid communication with the suction inlet 134 and circulation jet outlets 136 to enable the pump 138 to circulate fluid through the conduit 132. In an embodiment where the conduit 132 is fluidly connected to the three-way valve 124 through a T-junction, both of the solenoids 125 and 126 remain closed during a circulation operation.

[0036] FIG. 5 depicts an exemplary process 600 for operation of the spa 100 during a cleaning process. In the discussion below, a reference to the process performing a function or action refers to a controller, such as controller 160, executing programmed instructions stored in a memory to operate one or more components of the printer to perform the function or action. Process 600 is described with reference to the spa 100 for illustrative purposes. In the process 600, the spa 100 partially drains liquid from the filled vessel 106 and refills the vessel 106 with water from the water main 120. In the spa 100, process 600 can be initiated manually through a command entered via the user interface device 161, or can be scheduled to run periodically.

[0037] Process 600 begins by opening the drain/fill port 112 to enable liquid in the vessel 106 to drain through the conduit 156 (block 604). In the spa 100, the controller 160 opens the solenoid 126 in the valve 124 to place the drain/fill port 112 in fluid communication with the drain conduit 172. In some embodiments, the controller 160 also deactivates any of the heaters 116A - 116B and 140 at the beginning of the process 600. As liquid drains from the vessel 106, the controller 160 measures either or both of the volume of liquid that has drained from the vessel 106 or the level of liquid in the vessel 106 (block 608). In one configuration, the controller 160 monitors the flow of liquid through the drain/fill port 112 with the flow sensor 154 or pressure sensor 145. In another configuration, the controller 160 monitors the level of liquid in the vessel 106 with the pressure sensor 145. The controller 160 can also monitor both the volume of liquid that flows through the drain/fill port 112 and level of liquid in the vessel 106.

[0038] The controller 160 monitors the drainage of liquid through the drain/fill port 112 in the spa 100 until a partial drain has been completed (block 612). A partial drain refers to draining only a fraction of the liquid in the vessel 106, such as draining approximately one-half of the liquid or draining a range of approximately 25% to 75% of the liquid held in the vessel 106. The partial drain removes a sufficient amount of liquid from the vessel 106 to clean at least some contaminants from the liquid while also reducing the usage of water and treatment chemicals in in comparison to draining all of the liquid from the vessel 106. The controller identifies the completion of a partial drain in response to either a predetermined volume of liquid draining through the drain/fill port 112 or the level of liquid in the vessel 106 dropping to a predetermined level.

[0039] After the partial drain process is completed, the controller 160 operates the valve 124 to switch the drain/fill port 112 from fluid communication with the drain 170 to be in fluid communication with the water main 120 instead (block 616). In the valve 124, the solenoid 126 closes to remove the drain/fill port 112 from fluid communication with the drain 170, and the solenoid 125 opens to place the water main 120 in fluid communication with the drain/fill port 112. Liquid water flows from the water main 120 into the vessel 106 through the drain/fill port 112. The fluid pressure of the water main 120 is sufficient to fill the vessel 106, but in an alternative configuration, an auxiliary pump provides additional pressure to fill the vessel 106.

[0040] As the vessel 106 fills with liquid, the controller 160 measures the volume of liquid added to the vessel 106 and/or the level of liquid in the vessel 106 with reference to signals received from the level and/or flow sensors (block 620). In one configuration, the controller 160 monitors the flow of liquid through the drain/fill port 112 with the flow sensor 154. In another configuration, the controller 160 monitors the level of liquid in the vessel 106 with the pressure sensor 145. The controller 160 can also monitor both the volume of liquid that flows through the drain/fill port 112 and level of liquid in the vessel 106.

[0041] The solenoid 125 in the valve 124 remains open until the partial fill process is completed (block 624). In one embodiment, the controller closes the solenoid 125 in the valve 124 once a volume of liquid passes through the drain/fill port 112 that corresponds to the volume of liquid that was drained through the drain/fill port 112 during the partial drain process. In another embodiment, the controller closes the solenoid 125 in the valve 124 once the pressure sensor 145 indicates that the vessel 106 is holding a predetermined level of liquid. In one embodiment, the refill process stops when the vessel 106 refills to the same level prior to the partial drain process, although the controller 160 can be configured to halt the refill process to leave a portion of the vessel 106 unfilled for manual addition of various additives including treatment chemicals.

[0042] Once the partial fill process is completed, the controller 160 operates the solenoid 125 to close the valve 124 and remove the drain/fill port 112 from fluid communication with both the water main 120 and drain 170 (block 628). In an embodiment where liquid enters the vessel 106 through the drain/fill port 112, the valve 124 or the conduit 156 includes an anti-siphon device to prevent back flushing of water into the water main 120.

[0043] In process 600, the controller 160 can optionally activate the housing heaters 116A and 116B to provide heat to the liquid in the vessel 106 (block 632). In alternative embodiments, the controller 160 activates other heaters to warm the liquid in the vessel 106 or activates an external water heater that supplies heated water to the tub. Additionally, the controller 160 can optionally activate the pump 138 and infrared heater 140 to begin circulation and heating of liquid from the vessel 106 (block 636). At any point during operation of the spa 100, including during process 600, the controller 160 can deactivate any heater in or connected to the spa 100, including infrared heaters 116A, 116B, and 140, with reference to a temperature of the liquid in the vessel 106 or in the fluid conduit 132. In another embodiment, the controller 160 selectively reduces the electrical current and corresponding infrared output of the infrared heaters to heat the liquid without exceeding the operating temperatures. The controller 160 deactivates the infrared heaters when the liquid temperature exceeds either a predetermined temperature entered by a user through the user interface 161, or a predetermined maximum operating temperature for the spa 100. The controller 160 operates the infrared heaters to provide heated water to the spa 100 within a controlled temperature range.

[0044] The embodiments described above depict an illustrative embodiment of a spa 100, but alternative embodiments and configurations are also envisioned. For example, alternative embodiments of the spa 100 include only a selected subset of the infrared heaters 116A, 116B, and 140 depicted above, or include additional infrared heaters to heat the liquid.

[0045] The spa 100 includes integrated components that enable the controller 160 to automatically drain and refill liquid held in the vessel 106. Modifying existing spas with the configuration of spa 100 would, however, be difficult. FIG. 6A - FIG. 6C depict a liquid management device 800 that is connected to an existing spa 826 to control an automatic drain and refill process. The liquid management device 800 includes housing 804 holding a valve 808, bidirectional fluid coupling 825, pressure sensor 840, outlet fluid coupling 829, inlet fluid coupling 833, controller 812, antenna 814, and electrical power supply 816.

[0046] The valve 808 controls a flow of water between the bidirectional fluid coupling 825, output fluid coupling 829, and inlet fluid coupling 833. The inlet fluid coupling 833 is fluidly connected to the water main 120 with a fluid conduit 832. The fluid conduit 832 is typically a pipe or hose and the inlet fluid coupling 833 can include a threaded connector or flange to connect the fluid conduit 832 to the liquid management device 800. The outlet fluid coupling 829 is similarly configured to connect to an output fluid conduit 828 that connects to the drain 170. The bidirectional fluid coupling 825 is similarly configured to be connected to the fluid vessel in the spa 826 with a fluid conduit 824. The fluid conduit 824 is connected to a drain/fill port 827 in the vessel in the spa 826. The solenoid-controlled stopper 820A opens and closes to control a flow of liquid from the water main 120 through the valve 808 to the bidirectional fluid coupling 825. The solenoid-controlled stopper 820B opens and closes to control a flow of liquid from the spa 826 through the valve 808 to the drain fluid coupling 829. During operation, liquid drains from the spa 826 through the bidirectional fluid coupling 825 to the drain 170, and liquid flows from the water main 120 through the bidirectional fluid coupling 825 to fill the spa 826 through the drain/fill port 827.

[0047] In the liquid management device 800, the controller 812 is a digital control device implemented with one or more digital logic devices. The controller 812 can be implemented with general or specialized programmable processors that execute programmed instructions. The instructions and data required to perform the programmed functions are stored in memory associated with the processors or controllers. The processors, their memories, and interface circuitry configure the controller to perform the functions described herein for the liquid management device 800. Various embodiments of the controller 812 include programmable microcontrollers, microprocessors, field programmable gate arrays (FPGAs), and application specific integrated circuits (ASICs). Each of the circuits in the controller 812 can be implemented with a separate processor or multiple circuits can be implemented on the same processor. Alternatively, the circuits can be implemented with discrete components or circuits provided in VLSI circuits.

[0048] The controller 812 is operatively connected to a solenoid in each of the solenoid-controlled stoppers 820A and 820B, and to the pressure sensor 840. During operation, the controller 812 operates the solenoids to place either the outlet fluid coupling 829 or inlet fluid coupling 833 in fluid communication with the bidirectional fluid coupling 825. The pressure sensor 840 is located in the bidirectional fluid coupling 825. The liquid in the spa 826 generates pressure in the bidirectional fluid coupling, and the pressure sensor 840 generates a signal corresponding to the pressure. As described above, the level of pressure corresponds to the level of liquid in the spa 826, and the controller 812 identifies a level of liquid in the spa 826 with reference to the signals from the pressure sensor 840.

[0049] The controller 812 includes a combination of hardware and software to implement a wireless communication module that converts wireless signals received with the antenna 814 into digital data. In one embodiment, the controller 812 is a wireless communication module implemented as a Bluetooth or WIFI transceiver that can send and receive data with a wide range of electronic devices, including a smartphone 850. Other wireless communication modules include 802.11 wireless transceivers, infrared transceivers, or any other appropriate remote control device. In an alternative configuration, the liquid management device 800 includes a control interface that is integrated into the housing 804 or is connected to the housing 804 with a wired connection.

[0050] The smartphone 850 includes a software application that presents a remote control interface to an operator. The operator uses the remote control software to send commands to the controller 812. Examples of commands include a command to drain the spa 826, fill the spa 826 to a selected level, or to perform an automatic drain and refill process. The controller 812 can also transmit information about the spa 826, such as the level of liquid in the spa 826, to the smartphone 850. The operator can also configure the controller 812 to perform drain and refill operations with the liquid management device 800 at a predetermined time or at regular intervals.

[0051] In the liquid management device 800, the controller 812 and solenoids in the solenoid-controlled stoppers 820A and 820B receive electrical power from the power supply 816. In the example of FIG. 6A - FIG. 6C, the power supply 816 receives an alternating current (AC) electrical signal from an electrical utility 874 or any other suitable source of electric power and converts the AC electrical power to one or more direct current (DC) signals to operate the controller 812 and solenoid-controlled stoppers 820A and 820B. The power supply 816 is connected to the electrical utility 874 through a ground fault circuit breaker 818. In the event of a short circuit or other fault, the circuit breaker 818 opens to isolate the interior of the housing 804 from the electrical utility 874.

[0052] Referring to FIG. 6A, the liquid management system 800 is depicted with the valve 808 in a cutoff position. In the example of FIG. 6A - 6C, the valve 808 is a multi-solenoid valve, but alternative valve configurations, such as a ball valves or other three way valves, can also be used with the liquid management device 800. In the cutoff position of FIG. 6A, both of the solenoid-controlled stoppers 820A and 820B are closed and the bidirectional fluid coupling 825 is disconnected from both the outlet fluid coupling 829 and the inlet fluid coupling 833. The configuration of FIG. 6A prevents liquid from flowing into or draining from the spa 826 through the valve 808.

[0053] FIG. 6B depicts the liquid management system 800 with the valve 808 in a drain position. In FIG. 6B, the solenoid-controlled stopper 820B opens the valve 808 to place the outlet fluid coupling 829 in fluid communication with the bidirectional fluid coupling 825 while the solenoid-controlled stopper 820A remains closed. Liquid in the spa 826 flows through the spa drain/fill port 827, fluid conduit 824, and the bidirectional fluid coupling 825. The liquid then drains through the outlet fluid coupling 829 and fluid conduit 828 to the drain 170. In the configuration of FIG. 6B, the controller 812 monitors liquid pressure with the pressure sensor 840 to identify the level of liquid in the spa 826 as liquid drains from the spa 826. The controller 812 operates the solenoid-controlled stopper 820B to control the amount of liquid that drains from the spa 826. For example, the controller 812 can open the solenoid-controlled stopper 820B to drain all of the liquid from the spa 826, or to drain a portion of the liquid from the spa 826 until the liquid reaches a predetermined level.

[0054] FIG. 6C depicts the liquid management system 800 with the valve 808 in a fill position. In FIG. 6C, the solenoid-controlled stopper 820A opens the valve 808 to place the inlet fluid coupling 833 in fluid communication with the bidirectional fluid coupling 825 while solenoid-controlled stopper 820B remains closed. Liquid from the water main 120 flows through the fluid conduit 832 and inlet fluid coupling 833 through the valve 808 and to the spa 826 through the bidirectional fluid coupling 825 and fluid conduit 824. In the embodiment of FIG. 6C, the water main 120 generates sufficient water pressure to fill the spa 826 through the drain/fill port 827. In another embodiment, an optional pump can supply additional pressure to fill the spa 826. The controller 812 operates the solenoid-controlled stopper 820A to control the amount of liquid that fills the spa 826. During a calibration process, the spa 826 is filled to capacity and the controller 821 stores a pressure signal from the pressure sensor 840 in a memory. During a fill process, the controller 812 identifies when the pressure signal from the pressure sensor 840 reaches the pressure level stored in the memory and identifies that the spa 826 has been filled to capacity. The controller 812 can optionally be set to fill the spa 826 to different levels that are below the full capacity of the spa. Once the spa is filled to a predetermined level, the controller 812 closes the solenoid-controlled stopper 820A to return the valve 808 to the cutoff position depicted in FIG. 6A.

[0055] During operation the controller 812 operates the solenoid-controlled stoppers 820A and 820B in the valve as depicted in FIG. 6A - FIG. 6C to control the amount of liquid in the spa 826. In one operating mode, the controller 812 partially drains and then refills liquid that is already present in the spa 826. The solenoid-controlled stopper 820B opens from the cutoff position of FIG. 6A to the drain position of FIG 6B. Liquid drains from the spa 826 to the drain 170 until the controller 812 identifies that a predetermined amount of liquid, such as half of the liquid in the spa 826, has been drained with reference to the pressure sensor 840. The solenoid-controlled stopper 820B then closes and the solenoid-controlled stopper 820A opens as depicted in FIG. 6C to enable water from the water main 120 to flow into the spa 826. The controller 812 monitors the level of water in the spa 826 with the pressure sensor 840 and closes the solenoid-controlled stopper 820A as depicted in FIG. 6A once the spa 826 has been refilled. In different operating modes, the controller 812 can also completely drain the spa 826, fill an empty spa 826 to a predetermined level, or add additional water to the spa 826 if the level of liquid drops below a predetermined level during operation of the spa.

[0056] Those skilled in the art will recognize that numerous modifications can be made to the specific implementations described above. Therefore, the following claims are not to be limited to the specific embodiments illustrated and described above. The claims, as originally presented and as they may be amended, encompass variations, alternatives, modifications, improvements, equivalents, and substantial equivalents of the embodiments and teachings disclosed herein, including those that are presently unforeseen or unappreciated, and that, for example, may arise from applicants/patentees and others.

Furthermore, the application describes the following embodiments:

[0057]

A further embodiment provides a spa comprising:

a housing forming a vessel;
a first opening formed in the vessel;
a second opening formed in the vessel and fluidly coupled to the first opening through a fluid conduit;
a pump fluidly coupled to the fluid conduit;
a valve fluidly coupled to the first opening and the second opening through the fluid conduit; and
a controller operatively connected to the valve and the pump, the controller being configured to:

operate the valve to place the first opening in fluid communication with a drain and to operate the pump to pump liquid from the vessel through the first opening to the drain;
operate the valve to place the second opening in fluid communication with a water source to enable liquid to enter the vessel through the second opening; and
operate the valve to remove the first opening from fluid communication with the drain and the second opening from fluid communication with the water source and to operate the pump to pump liquid from the vessel through the first opening through the conduit and into the vessel through the second opening.

[0058] The spa of the further embodiment may further comprise:

a liquid level sensor fluidly coupled to the vessel and configured to generate a first signal in response to a level of liquid in the vessel being below a first predetermined level and a second signal in response to a level of liquid in the vessel being above a second predetermined level, the second predetermined level being greater than the first predetermined level; and
the controller being connected to the liquid level sensor and further configured to:

operate the valve to place the second opening in fluid communication with the water source in response to receiving the first signal from the liquid level sensor; and
operate the valve to remove the first opening from fluid communication with the drain and the second opening from fluid communication with the water source and to operate the pump in response to receiving the second signal from the liquid level sensor.

[0059] The spa of the further embodiment may further comprise:

an infrared heater located in the housing proximate to the vessel and configured to heat the liquid in the vessel; and
the controller being operatively connected to the infrared heater and further configured to:

activate the infrared heater in response to the valve placing the second opening in fluid communication with the water source.

[0060] In the spa of the further embodiment the controller may be further configured to:

deactivate the infrared heater in response to the valve placing the opening in fluid communication with the drain.

[0061] The spa of the further embodiment may further comprise:

an infrared heater positioned proximate to the fluid conduit to heat liquid in the fluid conduit; and

the controller being further configured to:

activate the infrared heater to heat liquid in the fluid conduit only when the valve removes the first opening from fluid communication with the drain and the second opening from fluid communication with the water source and the pump pumps liquid from the vessel through the first opening through the conduit and into the vessel through the second opening.

Claims

1. A spa comprising:

a housing forming a vessel;
an opening formed in the vessel;
a valve fluidly coupled to the opening;
a liquid flow sensor configured to measure liquid flow through the opening in the vessel; and
a controller operatively connected to the valve and the liquid flow sensor, the controller being configured to:

operate the valve to place the opening in

fluid communication with a drain to enable liquid within the vessel to drain from the vessel;
operate the valve to place the opening in fluid communication with a water

source to enable liquid to enter the vessel through the opening with reference to a signal from the liquid flow sensor, that indicates a predetermined volume of liquid has drained from the vessel; and
operate the valve to remove the opening from fluid communication with the drain and the water source in response to the controller identifying that the predetermined volume of liquid has entered the vessel.

2. The spa of claim 1, the predetermined volume of the liquid being less than a total volume of liquid held in the vessel, in particular one half of the total volume of liquid held in the vessel.

3. A spa comprising, in particular spa according to any of the preceding claims,
a housing forming a vessel;
an opening formed in the vessel;
a valve fluidly coupled to the opening;
a liquid level sensor positioned proximate to the opening and configured to generate a first signal in response to a level of liquid in the vessel being below a first predetermined level and a second signal in response to a level of liquid in the vessel being above a second predetermined level, the second predetermined level being greater than the first predetermined level; and
a controller operatively connected to the valve and the liquid level sensor, the controller being configured to:

operate the valve to place the opening in fluid communication with a drain enable liquid within the vessel to drain from the vessel;
operate the valve to place the opening in fluid communication with a water

source to enable liquid to enter the vessel through the opening in response to the first signal from the liquid level sensor; and
operate the valve to remove the opening from fluid communication with the drain and the water source in response to the second signal from the liquid level sensor.

4. The spa according to any of the preceding claims, further comprising:

a fluid conduit having an inlet formed in the housing in fluid communication with the vessel and an outlet formed in the housing in fluid communication with the vessel;
a pump operatively connected to the fluid conduit;
an infrared heater positioned proximate to the fluid conduit to heat liquid in the fluid conduit; and
the controller being operatively connected to the pump and the infrared heater and further configured to:

activate the pump to draw liquid from the vessel through the inlet of the fluid conduit and emit the liquid into the vessel through the outlet of the fluid conduit; and
activate the infrared heater in response to the pump activating.

5. The spa according to any of the preceding claims, wherein the infrared heater being located within the fluid conduit and/or wherein infrared heater engaging an outer circumference of the fluid conduit.

6. The spa of claim 3, the liquid level sensor being a pressure sensor.

7. The spa according to any of the preceding claims, further comprising:

an infrared heater located in the housing proximate to the vessel and configured to heat the liquid in the vessel; and
the controller being operatively connected to the infrared heater and further configured to:

activate the infrared heater in response to the valve placing the opening in fluid communication with the water source.

8. The spa of claim 7, the controller being further configured to:

deactivate the infrared heater in response to the valve placing the opening in fluid communication with the drain.

9. The spa according to any of the preceding claims, further comprising:

an infrared heater located in the housing proximate to the vessel and configured to heat the liquid in the vessel; and
the controller being operatively connected to the infrared heater and further configured to:

activate the infrared heater in response to the valve placing the opening in fluid communication with the water source.

10. A liquid management device for a spa, in particular for a spa according to any of the claims 1-9, comprising:

a housing;
an inlet fluid coupling formed in the housing and configured to be fluidly coupled to a liquid source;
an outlet fluid coupling formed in the housing and configured to be fluidly coupled to a drain;
a bidirectional fluid coupling formed in the housing and configured to be fluidly coupled to a tub in a spa;
a valve located in the housing and fluidly connected to the inlet fluid coupling, the outlet fluid coupling, and the bidirectional fluid coupling; and
a controller operatively connected to the valve and configured to:

operate the valve to place the inlet fluid coupling in fluid communication with the bidirectional fluid coupling to enable liquid from the liquid source to flow into the tub;
operate the valve to place the outlet fluid coupling in fluid communication with the bidirectional fluid coupling to enable liquid from the tub to flow to the drain; and
operate the valve to remove both the inlet fluid coupling and outlet fluid coupling from fluid communication with the bidirectional fluid coupling to prevent liquid from flowing through the valve.

11. The liquid management device of claim 10 further comprising:

a first solenoid configured to open and close a first stopper in the valve at the outlet fluid coupling;
a second solenoid configured to open and close a second stopper in the valve at the inlet fluid coupling; and
the controller being operatively connected to the first solenoid and the second solenoid and further configure to:

operate the first solenoid to place the outlet fluid coupling in fluid communication with the bidirectional fluid coupling;
operate the second solenoid to place the inlet fluid coupling in fluid communication with the bidirectional fluid coupling; and
operate the first and second solenoid to remove both the inlet fluid coupling and outlet fluid coupling from fluid communication with the bidirectional fluid coupling.

12. The liquid management device of claim 10 or 11 further comprising:

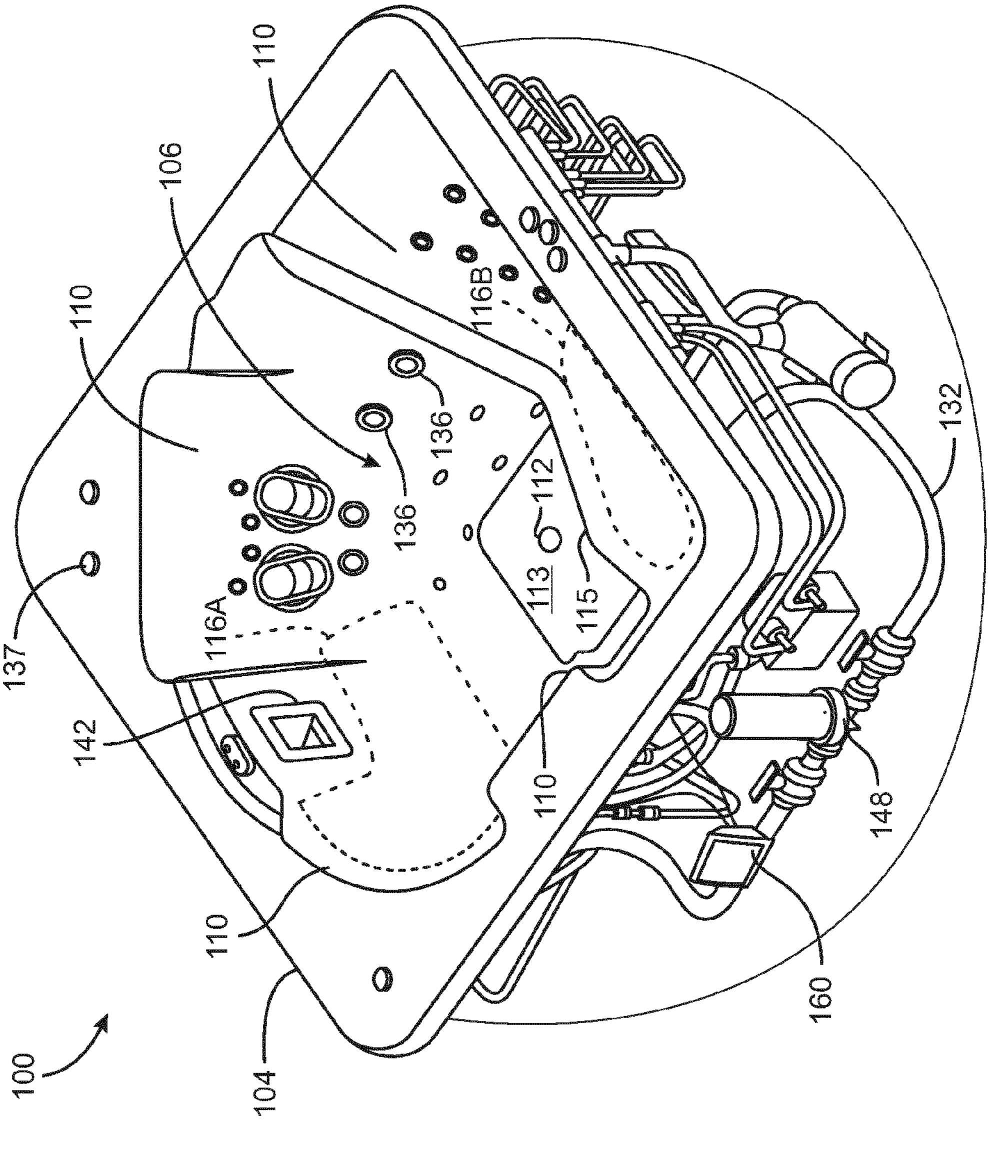
a pressure sensor positioned in the bidirectional fluid coupling and configured to generate a pressure signal corresponding to an amount of liquid in the tub; and
the controller being operatively connected to the pressure sensor and further configured to:

identify an amount of liquid in the tub as liquid drains from the tub and as liquid flows into the tub;
operate the valve to place the outlet fluid coupling in fluid communication with the bidirectional fluid coupling to drain liquid from the tub;
operate the valve to place the inlet fluid coupling in fluid communication with the bidirectional fluid coupling to enable liquid from the liquid source to flow into the tub in response to the identified amount of liquid in the tub reaching a first predetermined threshold; and
operate the valve to remove both the inlet fluid coupling and outlet fluid coupling from fluid communication with the bidirectional fluid coupling in response to the amount of liquid in the tub reaching a second predetermined threshold.

13. The liquid management device according to any of the claims 10-12, the first predetermined threshold corresponding to the tub being half filled with liquid and the second predetermined threshold corresponding to the tub being filled with liquid.

14. The liquid management device according to any of the claims 10-13, the controller further comprising:

a wireless communication module configured to receive a command signal from a remote wireless device, the controller being configured to operate the valve with reference to the command signal.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106
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115
116A
116B
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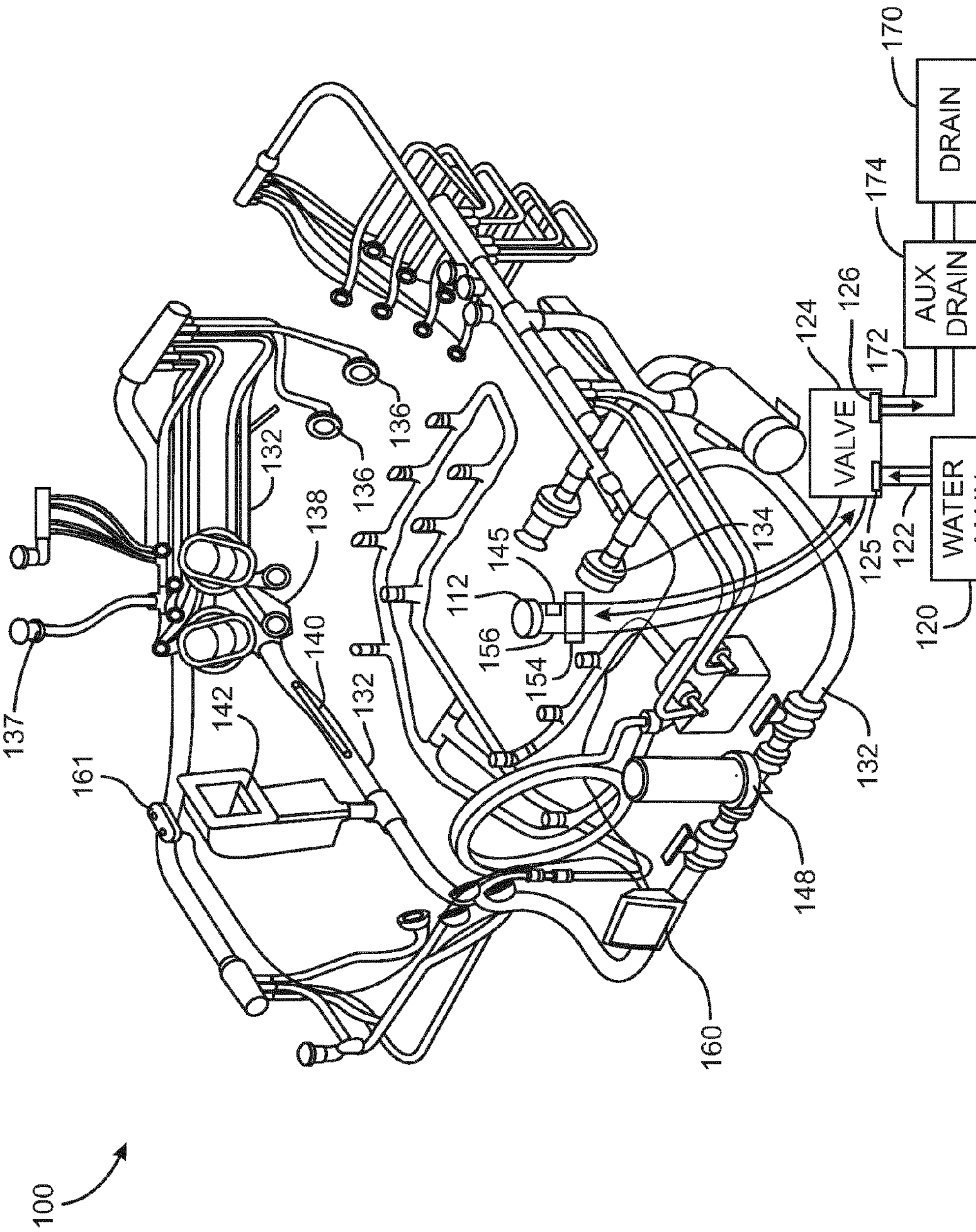
148
160

FIG. 1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156
154
134
124
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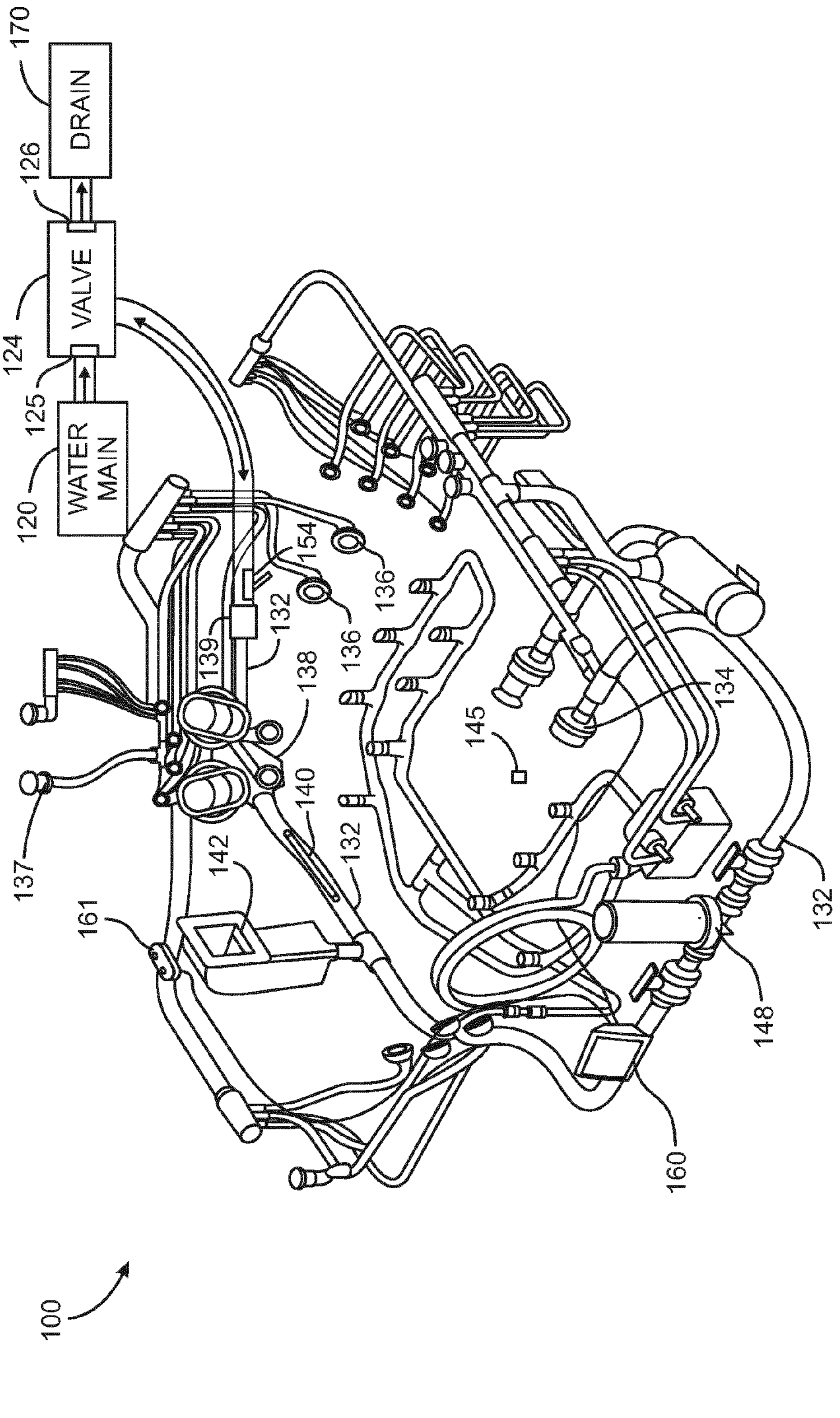
VALVE
WATER MAIN
125
122
120
AUX DRAIN PUMP
174
DRAIN
170
132
148
160

FIG. 2A



WATER MAIN
VALVE
DRAIN
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FIG. 2B

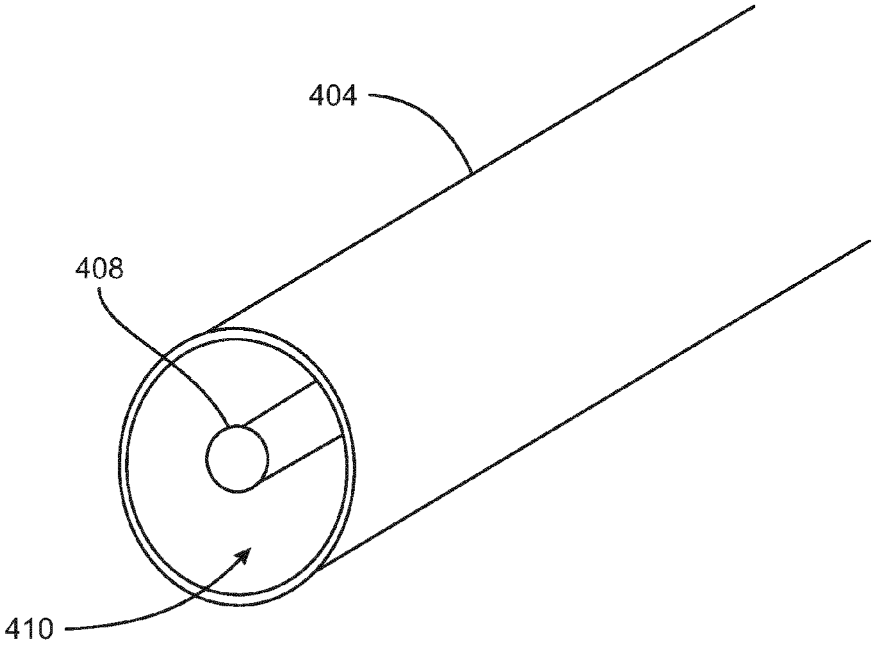


FIG. 3

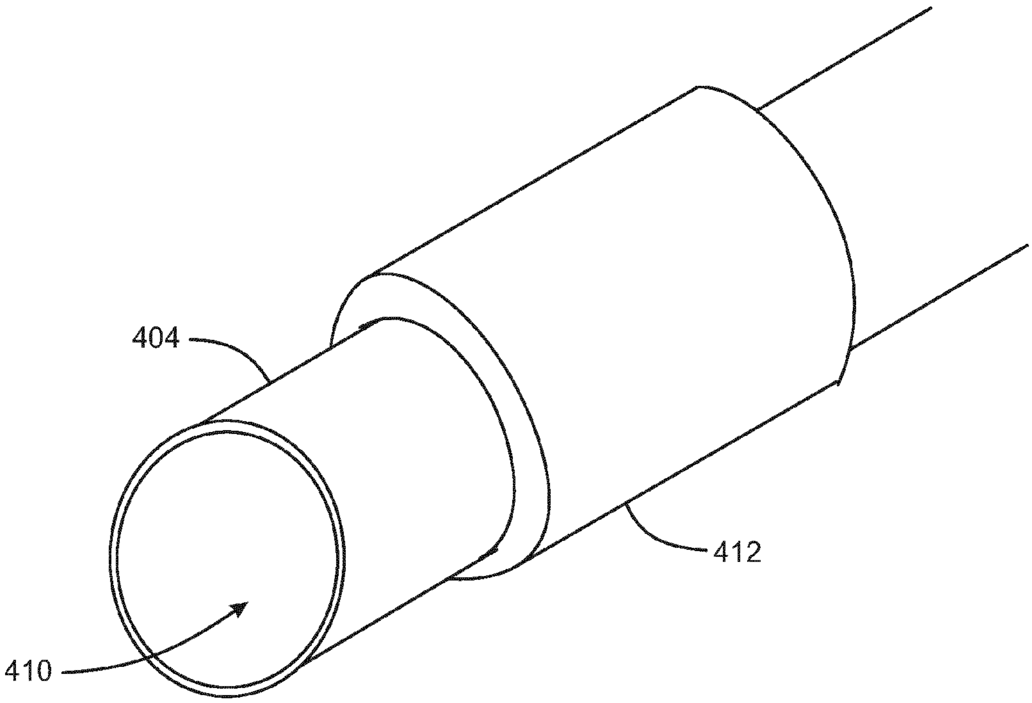


FIG. 4

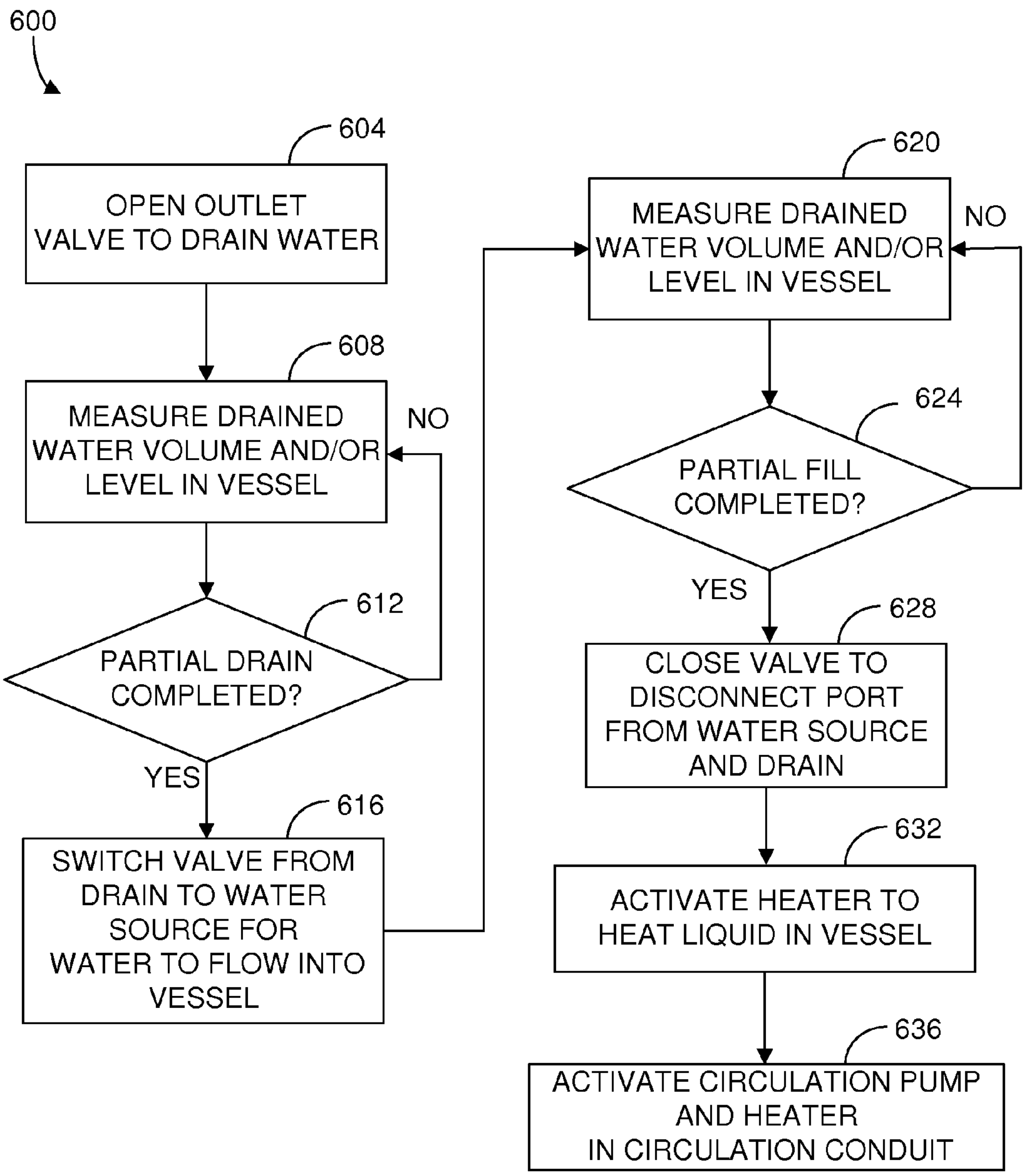
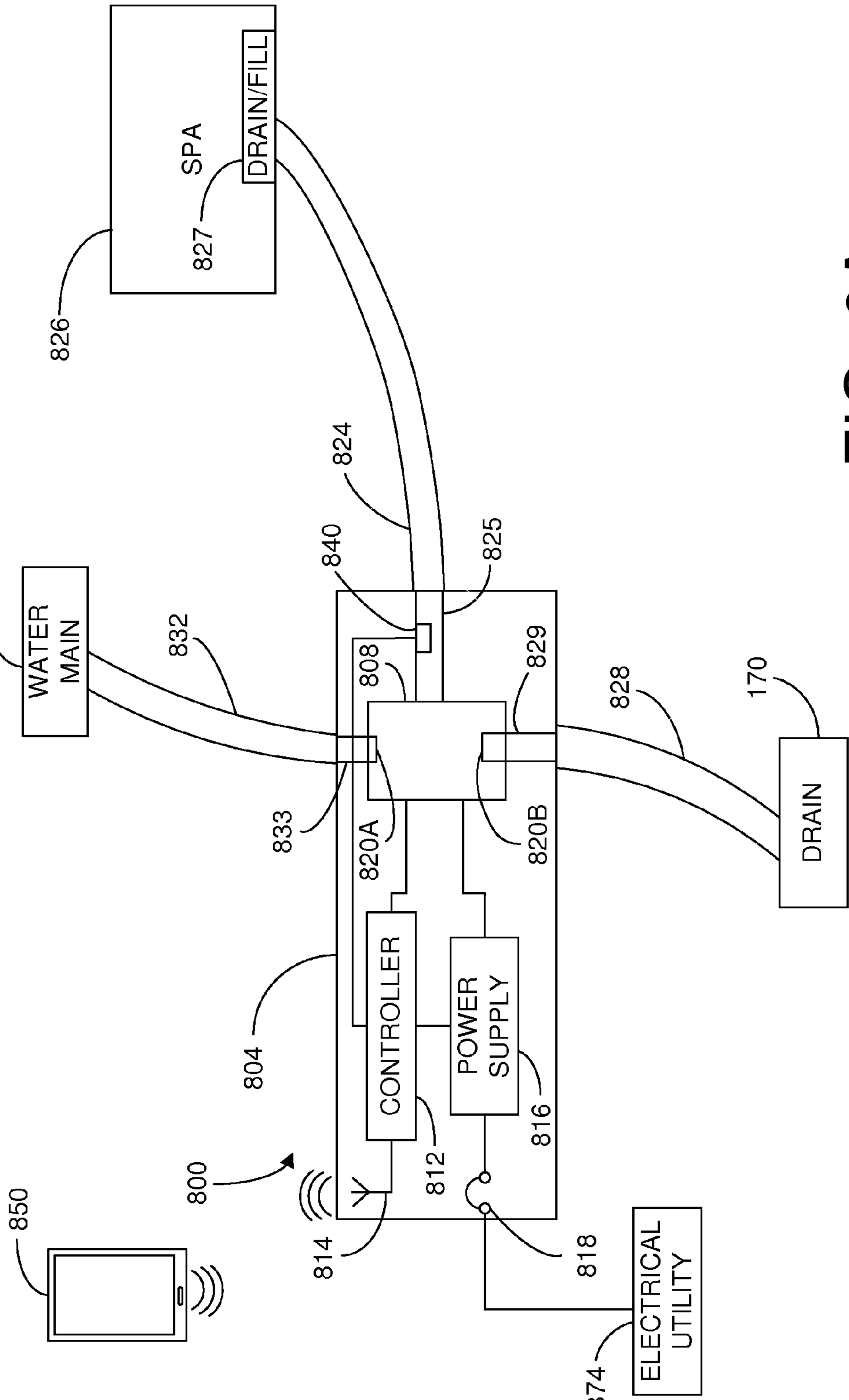

600
604
OPEN OUTLET VALVE TO DRAIN WATER
608
MEASURE DRAINED WATER VOLUME AND/OR LEVEL IN VESSEL
NO
612
PARTIAL DRAIN COMPLETED?
YES
616
SWITCH VALVE FROM DRAIN TO WATER SOURCE FOR WATER TO FLOW INTO VESSEL
620
MEASURE DRAINED WATER VOLUME AND/OR LEVEL IN VESSEL
NO
624
PARTIAL FILL COMPLETED?
YES
628
CLOSE VALVE TO DISCONNECT PORT FROM WATER SOURCE AND DRAIN
632
ACTIVATE HEATER TO HEAT LIQUID IN VESSEL
636
ACTIVATE CIRCULATION PUMP AND HEATER IN CIRCULATION CONDUIT

FIG. 5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820A
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CONTROLLER
POWER SUPPLY
804
812
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800
850
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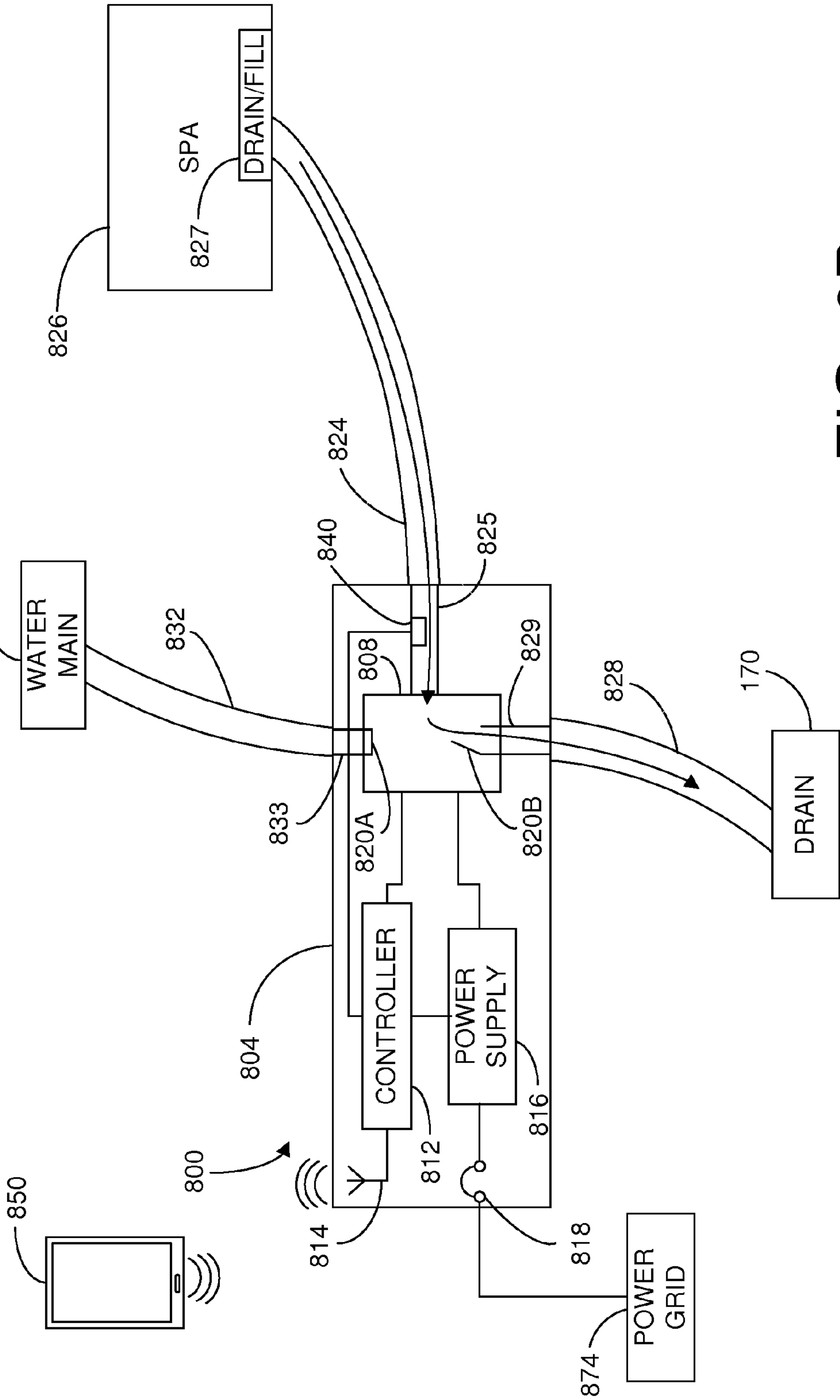
818
ELECTRICAL UTILITY
874

FIG. 6A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818
POWER GRID
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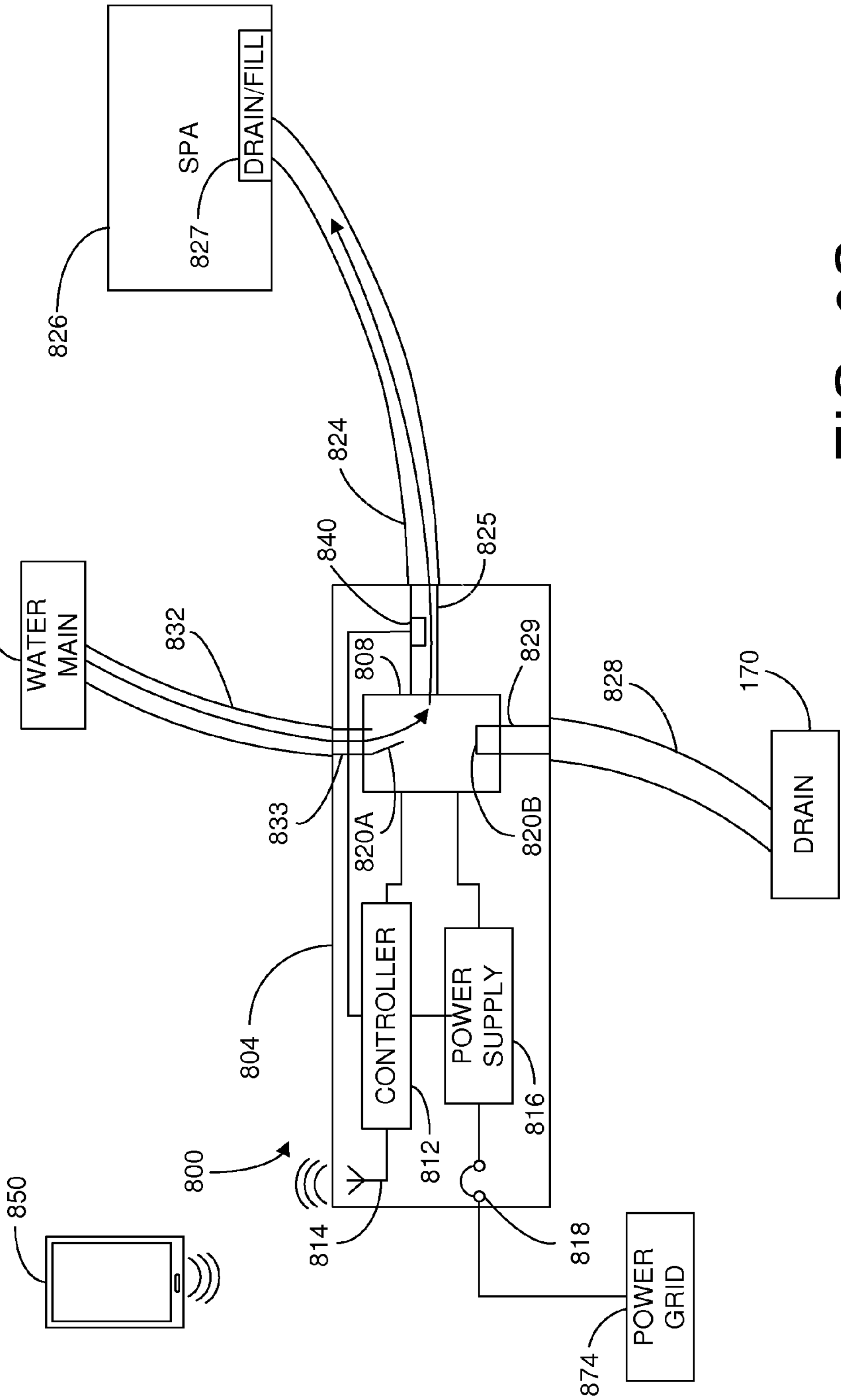
FIG. 6B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CONTROLLER
POWER SUPPLY
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POWER GRID
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FIG. 6C

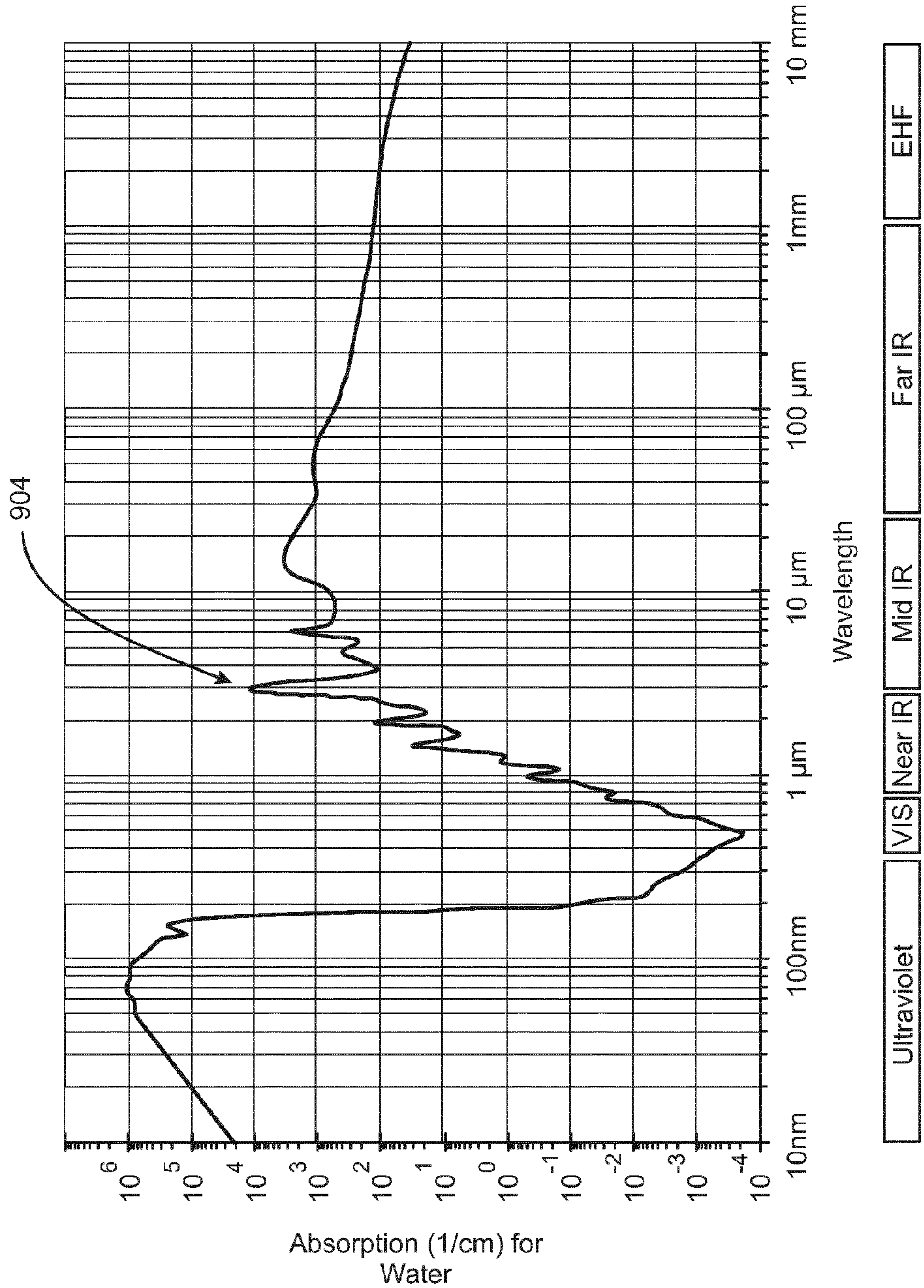

FIG. 7
PRIOR ART

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 13 18 3126

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2006/037655 A1 (FERRER BELTRAN JOSE M [ES]) 23 February 2006 (2006-02-23) * abstract; figures *	10,11,14	INV. A61H33/00 A61H33/02
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A	DE 41 08 719 A1 (SCHUESSLER GUENTER [DE]) 24 September 1992 (1992-09-24) * the whole document *	1-14	
A	EP 0 286 941 A1 (JACUZZI EUROP [IT]) 19 October 1988 (1988-10-19) * column 3, lines 13-17 * * column 4, lines 34-44; figures *	1-14	
A	EP 0 164 068 A2 (HOESCH & SOEHNE EBERHARD [DE]) 11 December 1985 (1985-12-11) * the whole document *	1-14	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	6 November 2013	Fischer, Elmar

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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E : earlier patent document, but published on, or after the filing date
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 18 3126

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82