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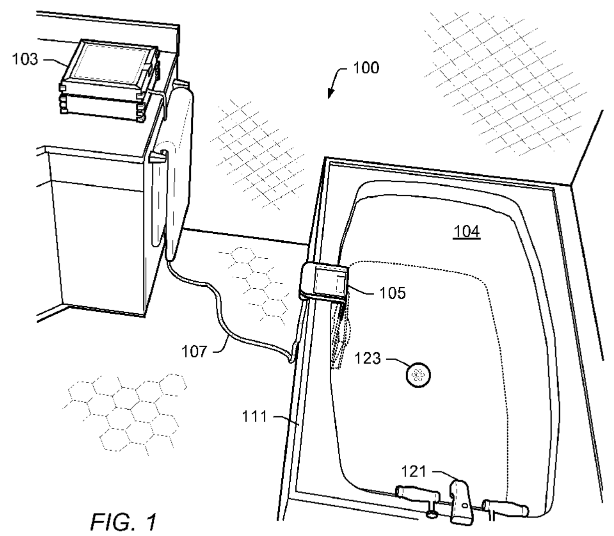

FIG. 1

(57) **Abstract:** In some embodiments, a bathtub heating system may detect a temperature of bathtub fluid (e.g., water, mud, etc.) in a bathtub and may apply heat to the bathtub fluid to maintain a substantially constant temperature (or to provide a user indicated and/or predetermined temperature/time profile). In some embodiments, the bathtub heating system may not use a temperature sensor. For example, the bathtub heating system may use a fluid level sensor to detect when the bathtub fluid in the bathtub is at a sufficient height to operate and may apply a predetermined amount of power to the heating elements to approximately maintain the temperature of the bathtub fluid in the bathtub.

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SYSTEMS AND METHODS FOR BATHTUB HEATING

BACKGROUND

1. Field of the Invention

[0001] The present invention relates generally to heaters and, more specifically, to bathtub heaters.

2. Description of the Related Art

[0002] While individuals may like to take long baths, their bathtub water may cool over time to an uncomfortable temperature. This may require the individual to add more hot water to the tub and drain out some of the cool water to keep the bath water at a constant level. Further, as water is added and drained, soap, bath scents, etc. may need to be added. This may interrupt the bath several times over the life of the bath.

SUMMARY OF THE INVENTION

[0003] In various embodiments, a bathtub heating system for heating a bathtub fluid (e.g., water, mud, etc.) in a bathtub may include a main unit and a bathtub heater coupled through tubing. In some embodiments, the bathtub heating system may detect the temperature of water in the bathtub and may apply heat to the bathtub fluid to maintain a constant temperature (or change the temperature of the bathtub fluid at the user's direction). In some embodiments, as a user adds hot or cold bathtub fluid to the bathtub, the bathtub heating system may adjust the heating of the bathtub heating system to approximately maintain the new detected temperature of the bathtub fluid (or to provide a user indicated and/or predetermined temperature/time profile). In some embodiments, the bathtub heating system may also dispense bath oils, soaps, scents, etc., to the bathtub fluid.

[0004] In some embodiments, the main unit may include three compartments (e.g., one compartment for storage space for items to use, for example, with the bath (such as scents, soaps, and bath oils), one compartment for storage of the bathtub heater and tubing, and one compartment (which may be hidden) for the main unit heating elements, pumps, controls, etc. Other configurations are also contemplated. In some embodiments, the pumps may include thermal expansion pumps (other pumps are also contemplated). In some embodiments, the main unit may heat a fluid and pump the fluid through the tubing to a heat exchanger element in the bathtub heater located at the bathtub. The heat exchanger element may place the fluid in thermal contact (which may not be actual contact) with bathtub fluid to add heat to the bathtub fluid. The fluid may then flow back through another compartment of the tubing to the main unit where the fluid may again be heated. In some embodiments, the fluid may be the bathtub fluid. The bathtub fluid may be pumped to the main unit, heated, and returned to the bathtub at the bathtub heater.

[0005] In some embodiments, the heated fluid at the bathtub heater may flow through an inlet nozzle and along an interior pathway of the bathtub heater. The interior pathway may include interior walls to direct the fluid throughout the interior of the heat exchanger element. In some embodiments, the fluid may be directed through an interior inlet through a driving mechanism with external blades to turn and direct external bathwater over the surface of the heat exchanger element. In some embodiments, the heat exchanger and/or driving mechanism may be mounted at an angle to the bathtub wall to direct water in a vertical direction upward (as well as side to side). Other directions are also contemplated (e.g., diagonally up or down, or any of other various directions). In some embodiments, the main unit and/or bathtub heater may be incorporated into the bathtub (e.g., in the sidewalls of the bathtub). In some embodiments, the bathtub may be a baby bathtub (other bathtubs are also contemplated).

[0006] In some embodiments, the bathtub heating system may include a heating element (e.g., wire) placed on the sides and/or bottom of the bathtub to heat the bathtub fluid in the bathtub. The bathtub heating system may have different zones of heating elements on the bathtub to direct different levels of heat to different portions of the bathtub.

[0007] In some embodiments, the bathtub heating system may use one or more temperatures sensors to monitor and approximately maintain the temperature of the bathtub fluid in the bathtub (or to provide a user indicated and/or predetermined temperature/time profile). In some embodiments, the bathtub heating system may not use a temperature sensor. For example, the bathtub heating system may use a fluid level sensor to detect when the bathtub fluid in the bathtub is at a sufficient height to operate and may apply a predetermined amount of power to the heating elements to approximately maintain the temperature of the bathtub fluid in the bathtub.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A better understanding of the present invention may be obtained when the following detailed description is considered in conjunction with the following drawings, in which:

[0009] FIG. 1 illustrates a bathtub heating system, according to an embodiment.

[0010] FIG. 2 illustrates a main unit, according to an embodiment.

[0011] FIGs. 3a-b illustrate components of the main unit, according to various embodiments.

[0012] FIGs. 4a-e illustrate a heat exchanger element for a bathtub heater, according to various embodiments.

[0013] FIGs. 4f-g illustrate a bathtub fluid exchanger, according to an embodiment.

[0014] FIG. 5 illustrates a side profile of an attachment mechanism for the bathtub heater, according to an embodiment.

[0015] FIG. 6 illustrates a dispenser unit on the bathtub heater, according to an embodiment.

[0016] FIG. 7 illustrates a tube clip, according to an embodiment.

[0017] FIG. 8 illustrates a cross section of the tube, according to an embodiment.

[0018] FIG. 9 illustrates internal components of the main unit, according to an embodiment.

[0019] FIG. 10 illustrates a flowchart of an embodiment of a method of operating the bathtub heating system.

[0020] FIG. 11 illustrates a flowchart of an embodiment of a method of operating the main unit.

[0021] FIGs. 12a-c illustrate a thermal water expansion pump, according to an embodiment.

[0022] FIG. 13 illustrates a flowchart of an embodiment for operating the thermal expansion pump.

[0023] FIG. 14 illustrates an electronic diagram of the bathtub heating system, according to an embodiment.

[0024] FIG. 15 illustrates a winding mechanism for winding the tubing of the bathtub heating system, according to an embodiment.

[0025] FIGs. 16a-b illustrate a rotatable housing for the tubing, according to an embodiment.

[0026] FIG. 17 illustrates a flowchart of an embodiment of a method for using the bathtub heating system 100.

[0027] FIGs. 18a-c illustrate a bathtub heating system incorporated into a bathtub, according to an embodiment.

[0028] FIG. 18d illustrates a bathtub heating system externally attached to the bathtub, according to an embodiment.

[0029] FIGs. 19a-b illustrate a bathtub heating system for a baby bathtub.

[0030] FIGs. 20a-c illustrate a heating element on a bathtub, according to an embodiment.

[0031] FIG. 21 illustrate panels for containing the heating elements, according to an embodiment.

[0032] FIG. 22 illustrates a removable bathtub panel for application of the heating element, according to an embodiment.

[0033] FIG. 23a-b illustrate an electrical schematic of the bathtub heating system, according to an embodiment.

[0034] FIG. 24 illustrates a flowchart for temperature managed bathtub heating system control, according to an embodiment.

[0035] FIG. 25 illustrates a method for manufacturing a bathtub, according to an embodiment.

[0036] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present invention as defined by the appended claims. Note, the headings are for organizational purposes only and are not meant to be used to limit or interpret the description or claims. Furthermore, note that the word “may” is used throughout this application in a permissive sense (i.e., having the potential to, being able to), not a mandatory sense (i.e., must). The term "include", and derivations thereof, mean "including, but not limited to". The term “coupled” means “directly or indirectly connected”.

DETAILED DESCRIPTION

[0037] FIG. 1 illustrates bathtub heating system 100, according to an embodiment. Bathtub heating system 100 may include main unit 103 and bathtub heater 105 coupled by tube 107. In some embodiments, bathtub heating system 100 may detect the temperature of bathtub fluid 104 (e.g., water, mud, etc.) in bathtub 111 and may apply heat to bathtub fluid 104 to offset cooling of bathtub fluid 104 (e.g., environmental cooling including loss of heat to the air, through the sides of bathtub 111, etc.) (other sources of heat loss are also contemplated). While embodiments presented herein disclose heating bathtub fluid 104, it is to be understood that bathtub heating system 100 may also be used to heat a fluid in other containers. In some embodiments, bathtub 111 may include a bottom and side walls (each of the bottom and side walls including an interior and exterior surface (e.g., interior bottom surface 2073, exterior bottom surface 2275, interior side wall surface 2071, and exterior side wall surface 2070 (e.g., see FIGs. 20c and 22)). The bathtub 111 may be made of iron, steel, plastic, etc. The bathtub 111 may further include a faucet for receiving the bathtub fluid 104 and a drain 123 for allowing a bathtub fluid 104 to exit the bathtub 111. Bathtub heating system 100 may monitor the temperature of bathtub fluid 104 and may apply the heat needed to maintain the temperature of bathtub fluid 104 (e.g., approximately 1800 watts (other power requirements are also contemplated)). The temperature may be monitored directly or indirectly by measuring a temperature associated with bathtub fluid 104 (e.g., measuring the temperature of bathtub fluid 104, a temperature of a component in thermal contact with bathtub fluid 104, etc). In some embodiments, the temperature of the bathtub fluid may not be monitored (e.g., a predetermined amount of power may be applied to a heating element when sufficient bathtub fluid is detected in the bathtub (e.g., by a fluid level sensor)). In some embodiments, the bathtub fluid 104 may be heated without being circulated in the bathtub (in some embodiments, the bathtub fluid may be circulated in the bathtub 111). In some embodiments, as a user adds hot or cold bathtub fluid 104 (e.g., hot or cold water) to bathtub 111, bathtub heating system 100 may adjust the heating of bathtub heating system 100 to approximately maintain the new detected temperature of bathtub fluid 104 (or to provide a user indicated and/or predetermined temperature/time profile). For example, if bathtub heating system 100 detects a large change in temperature (e.g., approximately in a range of +2 to -2 degrees Fahrenheit (F) (or, for example, approximately in a range of +5 to -5 degrees F) in a time approximately in a range of 1-2 seconds (or other time ranges, e.g., several minutes), bathtub heating system 100 may attribute the detected temperature change to user activity (e.g., adding bathtub fluid 104). Other ranges and time periods are also contemplated (e.g., if bathtub heating system 100 detects a relatively fast and large change in temperature approximately in a range of +5 to -5 degrees F under one minute in duration, bathtub heating system 100 may attribute the detected temperature change to user activity. Small variances in the temperature (e.g., approximately in a range of +0.2 to -0.2 degrees F (or, for example, approximately in a range of +1 to -1 degrees F) in a time approximately in a range of 1-2 minutes (or other time ranges, e.g., several seconds) may be attributed to environmental changes that need to be compensated for to maintain the original detected temperature. Other variance ranges are also contemplated. In some embodiments, bathtub heating system 100 may be operable to apply variable heat over time to bathtub fluid 104. For example, the amount of heat applied by bathtub heating system 100 to bathtub fluid 104 may decrease over time to decrease the temperature of bathtub fluid 104. In some embodiments, the amount of heat applied by bathtub heating system 100 to bathtub fluid 104 may increase over time to increase the temperature of bathtub fluid 104. In some embodiments, bathtub heating system 100 may be adjustable (e.g., according to user input through one or more user controls) to increase or decrease the temperature of bathtub fluid 104. In some embodiments, bathtub heating system 100 may not have user controls. In some embodiments, bathtub heating system 100 may be operable to fit a large selection of bathtubs 111. For example, bathtub heating system 100 may be temporarily or permanently mounted to bathtub 111. In some embodiments, bathtub heating system 100 may dispense bath oils, soaps, scents, etc. (e.g., on a continuous or timed release).

[0038] FIG. 2 illustrates main unit 103, according to an embodiment. Main unit 103 may include lid 201 for top compartment 203 (e.g., configured as a tray). Interior 205 of top compartment 203 may include storage space for items to use, for example, with the bath such as scents 207, bath oils 209, etc. Other items may also be placed in top compartment 203. Other items may include non-bath water additive related articles that enhance the bathing experience such as scented candles, romantic novels, etc. Top compartment 203 may include sub compartments (e.g., through a system of dividers) for organizing scents 207, bath oils 209, etc. Lower compartment 211 may include the main unit components and/or bathtub heater 105 (see FIG. 3) under top compartment 203. In some embodiments, lower compartment 211 may have hole 213 (e.g., formed through a gap in lid 215) to allow tubing 107 to extend out of lower compartment 211 during operation (e.g., when lid 215 is closed). In some embodiments, main unit 103 may have a "jewelry box" type design. In some embodiments, the outer design may match a bathroom theme and/or be customizable (e.g., through applications of paint, stickers, etc.) Other designs are also contemplated. In some embodiments, main unit 103 may have dimensions of approximately 10 inches wide by 10 inches length-wise by 5 inches height-wise. Other dimensions are also contemplated. For example, additional size may be needed for larger heating elements and/or pumps. In some embodiments, top compartment 203/ lower compartment 211 for main unit 103 may be made of wood. In some embodiments, the wood may be treated and/or sealed to be water resistant and/or water proof. Other materials are also contemplated. For example, a plastic may be used that is configured to look like wood (e.g., using an external paint or internal plastic coloring). Other configurations of main unit 103 are also contemplated. For example, main unit 103 may be incorporated into bathtub 111 (e.g., see FIGs. 18a-c) or externally mounted (e.g., see FIG. 18d).

[0039] FIGs. 3a-b illustrate components of main unit 103, according to various embodiments. As seen in FIGs. 3a-b, several configurations of compartments in main unit 103 are contemplated. For example, as seen in FIG. 3a, main unit 103 may include compartments 303 and 301 for the various main unit components. As seen in FIG. 3b, main unit 103 may include three compartments (e.g., one compartment (e.g., top compartment 203) for storage space for items to use, for example, with the bath (such as scents, soaps, and bath oils), one compartment 307 for storage of bathtub heater 105 (which may include heat exchanger element 305) and tubing 107, and one compartment 304 (which may be hidden) for main unit components 301 such as heating elements, pumps, controls, etc. In some embodiments, compartment 307 may be user accessible and compartment 304 may not be user accessible. Other configurations are also contemplated. In some embodiments, lower compartment 211 may include compartments 307 and 304 (e.g., accessible by raising compartment 203 which may be hinged to compartment 211). Other attachments are also contemplated (e.g., compartment

203 may lift off of compartment 211, for example, without a hinge). As seen in FIG. 3b, compartment 307 may also include attachment mechanism 501 for bathtub heater 105. Positioning element 421, mounted to attachment mechanism 501, may fold up along hinge 599 (or other flexible joint) between tube receiver 511 and extension arm 509 and may be placed in lower compartment 211 (e.g., in compartment 307). Other packaging configurations are also contemplated (e.g., compartments 301 and 303 as seen in FIG. 3a may include various components of bathtub heating system 100). Heat exchanger element 305 (and/or positioning element 421) and tubing 107 may be pulled out of compartment 307 during installation. If separate, heat exchanger element 305 may be inserted into a slot of positioning element 421 (and may snap into place). Other attachments are also contemplated. Positioning element 421 may then be mounted to the side of bathtub 111 to submerge bathtub heater 105 in bathtub fluid 104. Other configurations/arrangements of main unit 103 are also contemplated (e.g., with additional or fewer compartments).

[0040] In some embodiments, main unit 103 may heat fluid 419 (e.g., see FIGs. 4a-g) and pump fluid 419 through tube 107 to heat exchanger element 305. Heat exchanger element 305 may place fluid 419 in thermal contact (which may not be actual contact) with bathtub fluid 104 to add heat to bathtub fluid 104. In some embodiments, fluid 419 may be bathtub fluid 104 (e.g., as seen in FIGs. 4f-g) which may be pumped to main unit 103 to be heated prior to being pumped to bathtub heater 105 (which, in this embodiment, may not have heat exchanger element 305, but may pump heated bathtub fluid 104 into bathtub 111). Fluid 419 may then flow back through another tube and/or another chamber of tube 107 to main unit 103 where fluid 419 may again be heated. For example, tube 107 may be a dual chamber tube or may comprise two or more tubes (e.g., one tube for outward flow of fluid 419 and another tube for return flow of fluid 419). In some embodiments, fluid 419 may not come in fluid contact with bathtub fluid 104, but may instead deliver heat to bathtub fluid 104 through bathtub heater 105 to prevent contamination of fluid 419 with contaminants in bathtub fluid 104. In some embodiments, fluid 419 may be distilled water. Other fluids are also contemplated (e.g., oil). In some embodiments, additives may be added to fluid 419. For example, antifreeze may be added to fluid 419 to improve heat transfer to/from fluid 419. Other additives are also contemplated.

[0041] FIGs. 4a-g illustrate heat exchanger element 305 (which may be mounted in attachment mechanism 501), according to various embodiments. In some embodiments, heated fluid 419 from tube 107 may flow through inlet nozzle 401 and along an interior pathway of heat exchanger element 305. The interior pathway may include an interior routing element (e.g., interior walls 405). Interior walls 405 may extend between top plate 491 and lower plate 493 of bathtub heater 105 to direct fluid 419 throughout the interior of heat exchanger element 305. For example, the flow path may direct fluid 419 to flow throughout a substantial portion of the interior volume of bathtub heater 105. Other configurations of interior walls 405 are also contemplated.

[0042] In some embodiments, fluid 419 may be directed through interior inlet 407 through driving mechanism 411 and through interior outlet 409 to continue along the interior path. Fluid 419 may flow, for example, over one or more internal blades 433 in driving mechanism 411 which may be coupled through shaft 415 to exterior blades 413. Exterior blades 413 may thus turn and direct external bathtub fluid 104 over the outer casing (e.g., which may include top plate 491 and lower plate 493) of heat exchanger element 305 (e.g., see fluid flow lines 417 in FIG. 4e). In some embodiments, driving mechanism 411 may be driven by low voltage direct current (DC) motor 427 (e.g., as seen in FIG. 4d). In some embodiments, motor 427 may be powered through power received through wires co-extruded with tubing 107. Other power sources are also contemplated. In some embodiments, motor 427 may be coupled to heat exchanger element 305 (e.g., through plate 429). Other driving mechanisms are also contemplated. Fluid 419 may flow out of outlet nozzle 403 and back into tube 107 to return to main unit 103. In some embodiments, heat exchanger element 305 may have a heat exchanging face (e.g., the outer surfaces of top plate 491 and/or lower plate 493) of dimensions 5 inches wide by 5.44 inches long. Other dimensions are also contemplated. In some embodiments, heat exchanger element 305 may be made of an aluminum casting (e.g., to increase heat transfer rates). Other materials and manufacturing techniques are also contemplated. In some embodiments, heat exchanger element 305 may include one or more fins 499 (e.g., on top plate 491 and/or lower plate 493) to enhance heat exchange between heat exchanger element 305 and bathtub fluid 104.

[0043] As seen in FIG. 4e, in some embodiments, heat exchanger element 305 and/or driving mechanism 411 may be mounted at an angle to the top of the bathtub wall (e.g., through positioning element 421) to direct bathtub fluid 104 in a vertical direction upward (as well as side to side) (other directions are also contemplated). The vertical direction of bathtub fluid 104 may pull cooler bathtub fluid 104 from the bottom of bathtub 111 over heat exchanger element 305 and/or to the top of bathtub 111. In some embodiments, heat exchanger element 305 may be mounted substantially parallel to the top of the bathtub wall. Other mounting angles are also contemplated.

[0044] Also as seen in FIG. 4e, in some embodiments, bathtub fluid 104 may mix with scents or bath oils from cartridge 437. Cartridge 437 may be coupled to the exterior of heat exchanger element 305 (e.g., on top of heat exchanger element 305). Other placements of cartridge 437 are also contemplated. In some embodiments, cartridge 437 may receive scents/bath oils (e.g., through tube 441) from other cartridges/reservoirs (e.g., scent cartridge 517 shown in FIG. 5). In some embodiments, the cartridges may be purchased by users individually or on a subscription basis (e.g., a one year subscription of a quantity of scents per month). In some embodiments, other items may also be purchased by the user on an individual or subscription basis (e.g., one romantic chapter of a novel or a selection of candles each month). In some embodiments, the scents/oils may be birthstone featured scents, gold doubloons with aromatic crystals, scented candles, or essential oils. Other scents/oils are also contemplated. In some embodiments, cartridge 437 (e.g., mounted onto heat exchanger element 305) may be on top of bathtub heater 105 and may release scents through adjustable aperture 439 (e.g., with an aperture adjustable by a user and/or by bathtub heating system 100 through system inputs such as detected temperature of bathtub fluid 104). In some embodiments, a tube may direct the scents to driving mechanism 411 to disperse a heated version in bathtub fluid 104. Other cartridge and tube configurations and placements are also contemplated.

[0045] In some embodiments, heat exchanger element 305 may be coupled to positioning component 421 of bathtub heater 105. For example, screws (or other types of fasteners) may be used to fasten heat exchanger element 305 to positioning component 421 (e.g., through fastener holes 435a-d). In some embodiments, positioning component 421 may shield at least one side of heat exchanger element 305 from the bathtub user (e.g., heat exchanger element 305 may be coupled to the under side of plastic shield 423 which may shield the user from direct contact with bathtub heater 105 while allowing bathtub fluid 104 to contact bathtub heater 105 on the under side). Other configurations are also contemplated. In some embodiments, bathtub fluid 104 may flow through slots 521 (below shield 423 and above heat exchanger element 305) (see FIG. 5) and over heat exchanger element 305 (which may be inside positioning element 421). For example, motion of external blades 413 may pull bathtub fluid 104 in through slots 521 and direct bathtub fluid 104 over the surface of heat exchanger element 305. Bathtub fluid 104 may then leave positioning element 421 through slots on an opposing side of positioning element 421.

[0046] In some embodiments, as seen in FIGs. 4f-g, fluid 419 may be bathtub fluid 104. In some embodiments, bathtub fluid 104 may be pumped from bathtub heater 105 through tube 107. Bathtub fluid 104 may be pulled in through screen 471. Screen 471 may include a filter-to-filter bathtub fluid 104 before bathtub fluid 104 enters tube 107 (e.g., filtered of debris, etc.). In some embodiments, the filter may be replaceable and/or cleanable. Other locations of the filter are also contemplated. Bathtub fluid 104 may be pumped to main unit 103, heated, and pumped back to bathtub heater 105 through tube 107 (e.g., pumped back through a separate chamber of tube 107). Bathtub fluid 104 may then be released into bathtub 111 (e.g., through nozzle 473). Screen 471 and nozzle 473 may be mounted in housing 475. Housing 475 may be mounted inside bathtub 111 (e.g., through suction cup 477 as seen in FIG. 4f). In some embodiments, housing 475 may be mounted inside positioning element 421 (e.g., see FIG. 4g). In some embodiments, housing 475 may also be slanted (e.g., similar to heat exchanger 305 in FIG. 4e) and/or may also have cartridge 437 mounted on housing 475 for the delivery, for example, of oils and scents (similar to heat exchanger element 305 of FIG. 4e).

[0047] FIG. 5 illustrates a side profile of attachment mechanism 501 for bathtub heater 105, according to an embodiment. Bathtub heater 105 may be coupled to attachment mechanism 501 (e.g., through positioning element 421). Attachment mechanism 501 may include suction cup 505 that may be engaged/disengaged by motion of suction cup arm 507. As suction cup arm 507 is lifted, suction cup 505 may disengage from the side of bathtub 111. For example, suction cup arm 507 may be coupled to an insert (e.g., a thick wire) which may pull a small section of suction cup 505 up to break the seal. Other engagement/disengagement mechanisms are also contemplated. For example, suction cup 505 may be pulled into a fixed cone as suction cup arm 507 is pressed down. The cone may pull suction cup 505 into a configuration favorable to form a seal with the side of bathtub 111. When suction cup arm 507 is lifted, suction cup 505 may be pressed out of the cone and into a shape less favorable for a seal. As suction cup arm 507 is pressed down and along side of attachment mechanism 501, suction cup 505 may form a suction hold to the side of bathtub 111. In some embodiments, suction cup 505 may engage/disengage without use of suction cup arm 507. Other mechanisms for coupling attachment mechanism 501 to bathtub 111 are also contemplated (e.g., a large clip that extends over the side of bathtub 111, adhesive, etc.). Extension arm 509 may be rotated to adjust a depth of attachment mechanism 501 up and down (and, correspondingly, the depth of bathtub heater 105 with respect to a bathtub fluid level) in bathtub 111. In some embodiments, extension arm 509 may include a sliding friction fit that adjusts up and down (e.g., a bar sliding within another bar in which both bars have approximately the same diameter) to hold a depth of attachment mechanism 501 through the friction fit. Other extension arm configurations are also contemplated. Tube 107 may couple to attachment mechanism 501 through tube receiver 511. In some embodiments, tube 107 may be permanently coupled to tube receiver 511 or may be user-coupled to tube receiver 511 (e.g., by being inserted onto a nozzle of tube receiver 511) prior to use. A pathway for fluid 419 from tube 107 may be provided through extension arm 509 and to bathtub heater

105 (which may be located in positioning element 421). For example, internal tubes may connect to respective nozzles 401/403 to direct fluid flow to/from tube 107. In some embodiments, tube 107 may run through attachment mechanism 501 to connect to nozzles 401/403. Other fluid connection mechanisms are also contemplated. Tube clip 513 may hold tube 107 against an exterior of bathtub 111. Other holding locations are also contemplated.

[0048] FIG. 6 illustrates scent cartridge holder 517 on bathtub heater 105, according to an embodiment. In some embodiments, a scent may be placed in scent cartridge holder 517 to be delivered to bathtub fluid 104 directly or through bathtub heater 105 (e.g., through scent tube 441). For example, scent cartridge 517 may be coupled to a slot of attachment mechanism 501 or a scent, bath oil, etc. may be poured into scent cartridge holder 517 through inlet funnel 523. Other configurations are also contemplated. In some embodiments, scent cartridge holder 517 may be warmed by a heating element (e.g., inside holder 517). In some embodiments, the scent, bath oil, etc. may be warmed as warmed bathtub fluid 104 mixes with scent from cartridge 437 (e.g., scent flowing through aperture 439). In some embodiments, the scent, bath oil, etc. may not be warmed prior to mixing with bathtub fluid 104.

[0049] FIG. 7 illustrates tube clip 513, according to an embodiment. In some embodiments, tube clip 513 may include one or more suction cups 703 that may be engaged/disengaged by suction cup arms 701 (e.g., through a similar mechanism as described above with respect to suction cup arm 507). As suction cup arm 701 is lifted, suction cup 703 may disengage from the side of bathtub 111. As suction cup arm 701 is pressed down and along side of tube clip 513, suction cup 703 may form a suction hold to the side of bathtub 111. In some embodiments, suction cups 703 may engage/disengage without use of suction cup arms 701. Other mechanisms for attaching tube clip 513 to the side of bathtub 111 are also contemplated (e.g., adhesive). Tube clip 513 may receive tube 107 as the tube is pressed into cavity 705. In some embodiments, tube 107 may be inserted into cavity 705 (e.g., from the side if tube clip 513 is substantially enclosed along top 707 of tube clip 513.)

[0050] FIG. 8 illustrates a cross section of tube 107, according to an embodiment. In some embodiments, tube 107 may include warm chamber 801 and return chamber 803. Fluid 419 from main unit 103 may flow through warm chamber 801 to bathtub heater 105. Cooler fluid 419 may then return to main unit 103 through return chamber 803. Other configurations are also contemplated. For example, separate tubes may be used for warm chamber 801 and return chamber 803. In some embodiments, power lines 805a,b may also be embedded in tubing 107 to direct power to bathtub heater 105, from main unit 103, for powering measurement and control electronics. Additional lines may be included. For example, I2C control lines 807a,b between bathtub heater 105 and main unit 103 may be embedded in tube 107. In some embodiments, tube 107, power lines 805, and control lines 807 may be co-extruded (e.g., out of a thermoplastic). Other materials and configurations are also contemplated. In some embodiments, power and/or control lines 807 may be provided external to tubing 107 (e.g., in a separate wire). In some embodiments, power may be provided directly to bathtub heater 105 (e.g., through an AC cord or rechargeable battery). In some embodiments, wireless communications may be used in addition to or in place of control lines 807.

[0051] FIG. 9 illustrates internal components of main unit 103, according to an embodiment. In some embodiments, main unit 103 may include a pumping mechanism and a heating element (e.g., heating element 425). Heating element 425 may generate heat from one or more of electrical energy (e.g., a resistive element), gas, nuclear energy, solar energy, stored heat, chemical energy, or microwave energy. Other heating elements are also contemplated.

[0052] FIG. 10 illustrates a flowchart of an embodiment for heating and pumping fluid 419 in main unit 103. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0053] At 1001, fluid 419 may be pumped into main unit 103 (e.g., from return chamber 803 of tube 107) using a pumping mechanism. In some embodiments, the pumping mechanism may be a thermal expansion pump, a centrifugal pump, a kinetic pump or a positive displacement pump. Other pumps are also contemplated. In some embodiments, the pumping mechanism may include one or more expandable liners 901a,b (the operation of which is further described, for example, in FIGs. 11 and 12). In some embodiments, one or more pumping mechanisms may be included. In some embodiments, the pumping mechanisms may be placed in individual chambers with an inlet and exit check valve for fluid flow.

[0054] At 1003, fluid 419 entering main unit 103 may be heated by heating element 425. In some embodiments, heating element 425 may heat fluid 419 by converting electrical energy (e.g., applied through contacts 997 from electrical line 995) to heat (e.g., through an electrical current applied to a resistive element). In some embodiments, heating element 425 may include electrical insulation to prevent electricity from flowing through to fluid 419. The insulation may allow heat to pass through to fluid 419. Other heating elements and heating element configurations are also contemplated.

[0055] At 1005, heated fluid 419 may be pumped out of main unit 103 and into warm chamber 801 (e.g., pumped by thermal expansion pumps 1201).

[0056] At 1007, fluid 419 from warm chamber 801 may flow to bathtub heater 105 to heat bathtub fluid 104. In some embodiments, fluid 419 may flow through heat exchanger element 305 in thermal contact with bathtub fluid 104. In some embodiments, the fluid may be bathtub fluid 104 (and may be released into bathtub 111 after being heated as seen in FIG. 4g).

[0057] At 1009, fluid may return to main unit 103 through return chamber 803 (e.g., as a result of pumping action from thermal expansion pumps 1201).

[0058] FIG. 11 illustrates a flowchart of an embodiment of a method for implementing thermal expansion pump 1201. In some embodiments, thermal expansion pump 1201 may be more silent than other types of fluid pumps. However, in some embodiments, other types of fluid pumps may be used in addition to or in place of thermal expansion pump 1201. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0059] At 1101, expandable liner 901a may expand (e.g., see FIGs. 12-13 for additional information on the expansion of expandable liner 901). In FIG. 9, expandable liner 901a is in an expanded configuration and expandable liner 901b is in a collapsed configuration. As expandable liner 901 expands, it may displace fluid 419 from fluid pump chamber shield 903 (e.g., expandable liner 901a may displace fluid 419 from fluid pump chamber shield 903a and expandable liner 901b may displace fluid 419 from fluid pump chamber shield 903b) (see fluid flow lines 905). Other expandable elements may also be used. In some embodiments, fluid pump chamber shield 903 may substantially surround expandable liner 901 and may have one or more apertures 905 to allow fluid 419 to flow in and out of fluid pump chamber shield 903.

[0060] At 1103, as expandable liner 901a expands, fluid may leave chamber 919a through check valve 917b (e.g., in direction of arrow 921b). Other fluid connection types are also contemplated. Other numbers of check valves are also contemplated (e.g., two outlet check valves may be used). The fluid may flow out of check valve 917b and into outlet chamber 919c. In some embodiments, chambers 919a-d may be separate chambers linked by one or more check valves 921a-d to maintain fluid flow in one direction. Other chamber configurations are also contemplated.

[0061] At 1105, expandable liner 901a may collapse.

[0062] At 1107, as expandable liner 901a collapses, fluid may enter chamber 919a through check valve 917a (e.g., in direction of arrow 921a). Other fluid connection types are also contemplated. The fluid may flow into check valve 917a from heating chamber 919d. Heating chamber 919d may include heating element 425. Other placements of heating element 425 are also contemplated. In some embodiments, fluid 419 in heating chamber 919d may flow into heating chamber 919d through inlet valve 431 coupled to return chamber 803 of tube 107.

[0063] At 1109, as expandable liner 901 expands and collapses, fluid 419 in outlet chamber 919c may enter balance chamber 951 with fluid chamber 909 separated from compressible chamber 907 by piston head 911. As expandable liner 901 initially expands and displaces fluid 419, some of fluid 419 may displace piston head 911 (resulting in compression of a fluid (e.g., air) in compressible chamber 907).

[0064] At 1111, as the pressure of the fluid in chamber 907 rises, fluid 419 may begin to flow through outlet 913 and into warm chamber 801 of tube 107. As the expandable liner 901 expands and collapses, the pressure in chamber 907 may fluctuate, however, fluid 419 may continue to flow through outlet 913.

[0065] In an embodiment with two expandable liners 901 (e.g., as shown in FIG. 9), one expandable liner 901a may be expanding while the other expandable liner 901b is collapsing. Fluid 419 may also enter chamber 919b through check valve 917c and may exit chamber 919b through check valve 917d.

[0066] In some embodiments, expandable liners 901a,b may expand and collapse together. Other expansion/collapse timing configurations are also contemplated. Other numbers of expandable liners 901 are also contemplated (e.g., 3, 4, 10, etc.). In some embodiments, expandable liner 901 may be inside chamber 919a inside of main unit 103. Check valves 917 may prevent fluid 419 from moving back and forth in chamber 919a as expandable liner 901 expands and collapses. Fluid 419 exiting check valves 917b and 917d may enter outlet chamber 919c with chambers 907/909 (which may be isolated from the interior of main unit 103).

[0067] FIGs. 12a-c illustrate thermal expansion pump 1201 with expandable liner 901, according to an embodiment. FIGs. 12a-c illustrate embodiments of thermal expansion pump 1201 as seen in FIG. 9. Thermal expansion pump 1201 may include heating element 1203 surrounded by expandable liner 901 (also see the cross section illustrated in FIG. 12b). In some embodiments, expandable liner 901 may be an expandable rubber liner (other materials are also contemplated). In some embodiments, heating element 1203 may also be at least partially surrounded by inner shield 1299 (e.g., inside of expandable liner 901). Inner shield 1299 may include at least one opening 1251 to allow fluid to contact heating element 1203 and flow through to expand expandable liner 901. In some embodiments, inner shield 1299 may be made of a high temperature plastic extrusion. Other materials are also contemplated (e.g., stainless steel). In some embodiments, expandable liner 901 may be tight against inner shield 1299 when the fluid inside expandable liner 901 is not being expanded.

[0068] FIG. 13 illustrates a flowchart of an embodiment for operating thermal expansion pump 1201. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0069] At 1301, fluid 419 may enter inlet 1205 to at least partially fill an interior volume between heating element 1203 and expandable liner 901.

[0070] At 1303, inlet 1205 may be sealed closed. For example, an electric current flowing through solenoid coil 1207 may cause solenoid coil 1207 to push plunger 1209 closed. Washer 1211 (e.g., a rubber seal washer) at the end of plunger 1209 may form a seal on or in inlet 1205.

[0071] At 1305, current may be applied to heating element 1203. For example, current may be applied through contacts 1215 (which may be alternating current (AC) or direct current (DC) contacts). In some embodiments, contacts 1215 may be secured in place through end cap 1213 that also secures heating element 1203 and expandable liner 901. In some embodiments, end cap 1213 (and, for example, inlet 1205) may be made of brass. Other materials are also contemplated (e.g., plastic). In some embodiments, contacts 1215 may be insulated to apply the electrical current only to heating element 1203 (and not, for example, to end cap 1213 or surrounding fluid 419).

[0072] At 1307, fluid 419 inside expandable liner 901 may expand causing expandable liner 901 to expand. In some embodiments, fluid 419 may turn into steam during the expansion. In some embodiments, the amount of fluid 419 in expandable liner 901 (e.g., as determined by the amount of space between the components inside collapsed liner 901) and the amount of heat supplied from heating element 1203 may be coordinated to expand expandable liner 901 to a predetermined extent. In some embodiments, fluid pump chamber shield 903 (e.g., a plastic shell) may at least partially surround expandable liner 901 to limit expansion of expandable liner 901. Limiting the expansion may increase the life expectancy of expandable liner 901 by preventing over expansion (which may lead to weak spots and/or ruptures in expandable liner 901). In some embodiments, fluid pump chamber shield 903 may be coupled to end cap 1213 and inlet 1205. Other configurations for fluid pump chamber shield 903 are also contemplated. As expandable liner 901 expands, fluid 419 around expandable liner 901 may be displaced (causing, for example, fluid 419 to flow through check valve 917b).

[0073] At 1309, the current to heating element 1203 and solenoid coil 1207 may be discontinued.

[0074] At 1311, spring 1297 may bias open plunger 1209. As plunger 1209 opens, washer/seal 1211 may be moved away from inlet 1205. Fluid 419 (which may be at least partially expanded) in expandable liner 901 may at least partially leave the interior of expandable liner 901 through inlet 1205.

[0075] At 1313, expandable liner 901 may collapse. Collapsing liner 901 may create a void around expandable liner 901 which may be filled by surrounding fluid 419. Additional fluid 419 may enter chamber 919a through check valve 917a.

[0076] FIG. 14 illustrates an electronic diagram of bathtub heating system 100, according to an embodiment. In some embodiments, bathtub heating system 100 may use various pressure and temperatures sensors communicably coupled (e.g., through electrical connections) to one or more processors 1401 (e.g., Cypress PSOC (Programmable System-On-Chip) processors). Temperature sensors 1403a,b (e.g., thermocouple sensors) and pressure sensor 1405 (e.g., pressure transducer) coupled to main unit 103 may measure the temperature and pressure of fluid 419 in main unit 103 (and/or tube 107) and may convey these values/signals to processors 1401 (e.g., see FIG. 9 for approximate placement of the sensors; other placements are also contemplated). In some embodiments, redundant temperature and/or pressure sensors may be coupled to processors 1401. If one temperature and/or pressure sensor fails, this failure may be detected via a comparison (e.g., by one or more processors 1401) and bathtub heating system 100 may be deactivated by one or more processors 1401 (e.g., to insure a safe state). Bathtub heating system 100 may thus be a fail-safe and not a fail-operate system. Other configurations are also contemplated (e.g., bathtub heating system 100 may be a fail-operate system). The comparison may include comparing the readouts of two or more temperature sensors (if a temperature sensor reading, from the same fluid 419, stays relatively constant while another temperature sensor reading from a different temperature sensor, in the same fluid, is increasing or decreasing by an amount greater than a threshold, bathtub heating system 100 may determine that one of the temperature sensors is faulty. In some embodiments, the comparison may include comparing a sensor output (e.g., a pressure sensor output) to a predetermined model. Deviations from the expected model greater than a threshold may cause the system to determine that the sensor has failed. Processors 1401 may compare these temperatures and pressures to predetermined thresholds (e.g., safe operating temperature/pressure thresholds) and/or to each other. In some embodiments, thresholds may be predetermined and/or set by a user.

[0077] In some embodiments, bathtub heater 105 may also include processor 1401c coupled to one or more temperature sensors 1403c,d and/or pressure sensors (e.g., see FIG. 5 and FIG. 9 for approximate placement of the sensors; other placements are also contemplated). In some embodiments, temperature sensors 1403c,d may measure the temperature of bathtub fluid 104.

In some embodiments, temperature sensors 1403c,d may be placed out of the stream of heated bathtub fluid 104 (e.g., above positioning element 421). In some embodiments, one or more of temperature sensors 1403c,d may measure a temperature of fluid 419 in heat exchanger element 305. Processor 1401c may also be coupled to fluid level detection sensor 1407 (also see sensor 2051 in FIGs. 20a-b) to detect the presence and/or level of bathtub fluid 104 in bathtub 111. Processor 1401c may be communicably coupled (e.g., through I2C control lines 807a,b to processors 1401). Other communication pathways are also contemplated (e.g., processors 1401 may be wirelessly coupled). In some embodiments, one processor may be used instead of multiple processors.

[0078] In some embodiments, processors 1401 may operate and control the timing of valve coils 1207a,b and switches 1409a-f (e.g., solid state and/or in-line TRIAC switches (TRIode for Alternating Current Switches)) to the heating coils (e.g., heating element 425, and 1203a,b). If the detected temperatures exceed a predetermined temperature or a system failure is detected, processors 1401 may discontinue electrical current to one or more heating elements 425, 1203a,b (e.g., by switching off the current through switches 1409a-f). In one configuration, processor 1401a may operate valve coil 1207a and switch on current through switches 1409a-c if a temperature through temperature sensor 1403a indicates a temperature below an expected threshold and processor 1401b may operate valve coil 1207b and switch on current through switches 1409d-f if a temperature through temperature sensor 1403b indicates a temperature below a predetermined threshold. If one of processors 1401 detects a temperature exceeding a predetermined threshold, the switches corresponding to the processor may not be activated and current may not flow to one or more heating elements 425, 1203a,b. For example, a predetermined threshold for fluid 419 may be approximately 130 degrees F. Other thresholds are also contemplated (e.g., 140 degrees F). In some embodiments, two switches may be required (e.g., switches 1409b,e) to be on for a respective heating element (e.g., heating element 1203a) to activate (this may provide additional safety in case one or more sensors and/or processors fails and causes continuous or sporadic operation of their corresponding switch). Processors 1401 may also base operating decisions on comparing the pressure detected through pressure sensor 1405 to a predetermined pressure threshold and on information from processor 1401c. For example, processor 1401c may compare temperatures from temperature sensors 1403c,d (e.g., temperature sensor 1403c for the bathtub fluid temperature and temperature sensor 1403d for the fluid temperature) to predetermined temperature thresholds and may determine whether bathtub fluid 104 is in bathtub 111 (e.g., through a signal from fluid detection sensor 1407). Since a failed temperature sensor may not necessarily go to a detectable state, the differences in a multiple thermal sensor system may be used to detect a sensor failure that may result in bringing bathtub heating system 100 to a fail-safe condition. In some embodiments, only one temperature sensor (e.g., temperature sensor 1403c) may be used (other numbers of temperature and pressure sensors are also contemplated). In some embodiments, a predetermined threshold for the bathtub fluid temperature may be approximately 115 degrees F. Other bathtub fluid temperature thresholds are also contemplated. In some embodiments, processor 1401c may send the information from the sensors or a positive/negative signal to one or more processors 1401. Processors 1401 may use this information to further determine whether to activate/deactivate valve coils 1207a,b and/or switches 1409a-f. In some embodiments, processors 1401 may not activate (or may deactivate) thermal expansion pumps 1201 if the detected pressure of fluid 419 is greater than approximately 30 pounds per square inch (PSI). Other thresholds are also contemplated (e.g., approximately 40 PSI).

[0079] In some embodiments, processors 1401 may monitor the detected temperatures (e.g., of bathtub fluid 104) from temperature sensor 1403c to operate heating elements 425, 1203a,b to attempt to maintain the detected bathtub temperature constant. The detected fluid temperatures (e.g., from temperature sensors 1403a,b,d) may be used to determine a heat loss level in fluid 419 between main unit 103 and bathtub heater 105. Additional heat may be added if heat loss is above a predetermined threshold. Processors 1401 may use the detected pressure (e.g., from pressure sensor 1405) to determine if there is a break in the system (e.g., a loss in pressure) or, for example, if the hose is kinked (e.g., spike in pressure). In some embodiments, pressure sensor 1405 may be placed outside of both chambers 919a,b (e.g., to detect a rupture in expandable liner 901, or other failure). Placement outside both of chambers 919a,b in outlet chamber 919c may allow the pressure sensor to detect a pressure affected by both chambers 919a,b and the pressure inside tubing 107. In some embodiments, pressure sensors may be placed inside thermal expansion pumps 1201. Other sensor locations are also contemplated. In some embodiments, both fluid 419 in bathtub heating system 100 and the bathtub fluid temperature may be monitored and/or modeled.

[0080] In some embodiments, if an error is detected, the heating elements (e.g., heating elements 425, 1203a,b) and/or the pumps (e.g., thermal expansion pumps 1201a,b) may be deactivated and an indication (e.g., audio and/or visual) may be sent to the user. Other components may also be deactivated. Processors 1401 may reset after power is turned off and back on to bathtub heating system 100. In some embodiments, an indication of the error and/or error type may be stored on a FLASH memory (or other type of memory) accessible to processors 1401 (e.g., a FLASH memory resident on one or more of processors 1401). The

FLASH memory may be read by processors 1401 on start-up and, for example, if the error indicated is a severe error, bathtub heating system 100 may not be activated by processors 1401 when the user attempts to activate bathtub heating system 100. In some embodiments, processors 1401 may be programmed to recognize severe errors that indicate a permanent system malfunction (e.g., an inactive fluid level sensor) and potentially correctable errors (e.g., a spike in fluid pressure indicating tube 107 may have been kinked). If the error is potentially correctable, processors 1401 may attempt to resume normal operating when power is restored. Processors 1401 may store an indication of a severe error if two or more potentially correctable errors are detected in a row. Other error types are also contemplated.

[0081] In some embodiments, processor 1401c may be further coupled to on/off switch 1419 and one or more light emitting diodes (LEDs) 1421 to convey visual information to a user (e.g., unit operating, unit error, etc.) For example, a blue and a pink LED may be provided and may convey information to the user (e.g., pulsing blue – bathtub heating system 100 is waiting for the proper fluid level; steady blue – fluid level is correct, bathtub heating system 100 is monitoring the temperature; slight pink – temperature is stabilizing; solid pink – desired temperature is detected and is being maintained). Other information formats (e.g., auditory signals) are also contemplated. Other visual interfaces are also contemplated (e.g., an LED display).

[0082] In some embodiments, on/off switch may include additional switch options (e.g., a rheostat to increase/decrease temperature). Heating elements 425, 1203a,b may also be coupled to respective thermal switches 1411a-c (e.g., passive thermal switches) which may act as additional safety elements to cut current to a heating element if the local detected temperature exceeds a predetermined limit (e.g., a physical limit for a part in thermal switch 1411a-c). In some embodiments, passive pressure switches (e.g., which detect the pressure of fluid 419) may also be coupled to the power supply to cut power if the pressure exceeds or is below a predetermined threshold (e.g., as set by the physical characteristics of the passive pressure switch). Other sensors are also contemplated. In some embodiments, a power supply may include power source 1415 (e.g., an alternating current (AC) plug into an AC outlet), fuse 1417, and/or an AC/DC power supply/converter 1423 (e.g., with a transformer). In some embodiments, bathtub heating system 100 may also include a ground-fault-interrupter circuit that is collocated with the AC plug. In some embodiments, the AC power may be delivered to main unit 103 which may be remote from bathtub fluid 104 to increase user safety (e.g., lower the likelihood of electrocution due to a short) and for passing safety regulations. Direct current (e.g., from the AC/DC power supply) may power processors 1401 and switch lines (e.g., 3.3 volts). In some embodiments, the electrical power supplied to bathtub heater 105 may be small (e.g., 3.3 volts or less than equivalent power of 2 AA batteries). Other power levels are also contemplated. In some embodiments, DC power may be supplied to bathtub heater 105 (e.g., to power a heating element located in bathtub heater 105). In some embodiments, powering the heating element with DC power (e.g., to meet safety regulations) may require a substantial transformer diameter (e.g., to pass a DC current of approximately 100 amps at 18 volts). Other power levels are also contemplated.

[0083] In some embodiments, processors 1401 may compare readings (e.g., from various temperature and/or pressure sensors) and may shut down bathtub heating system 100 if one or more readings are not within predetermined operating limits. In some embodiments, processors 1401 may compare detected temperatures and/or pressures to a real-time computer model and/or simulation for bathtub heating system 100 and/or bathtub fluid 104 to predict the temperature of fluid 419 and/or bathtub fluid 104 that should be detected. In some embodiments, if the detected temperature is outside a range of predicted values (plus or minus a buffer range), bathtub heating system 100 may shut down (e.g., to prevent excessive heating). In some embodiments, a history of detected temperatures and/or pressures may be compared to a predicted track of temperatures and/or pressures. The comparison may be used to detect problems with bathtub heating system 100. For example, if one or more of thermal expansion pumps 1201 is activated, and the detected pressures do not indicate a rise in pressure, processors 1401 may determine that thermal expansion pump 1201 has failed (e.g., expandable liner 901 has ruptured). In some embodiments, an indication of the error (e.g., as a severe error) may be written to the FLASH memory. In some embodiments, the indication may be detected by processors 1401 the next time bathtub heating system 100 is activated. If the indication indicates a severe error (e.g., a ruptured expandable liner 901), processors 1401 may not allow bathtub heating system 100 to activate. In some embodiments, the indication may not indicate a severe error. For example, if a spike in pressure was detected (indicating, for example, a kinked tubing 107), processors 1401 may flash an indicator to the user (e.g., through LEDs) and may deactivate bathtub heating system 100 after writing an indication of the error (which may be indicated temporary) to the FLASH. Upon reactivation, processors 1401 may not inhibit activation (e.g., the user may have un-kinked tubing 107) until another error is detected.

[0084] FIG. 15 illustrates an embodiment of spooling mechanism 1501 for spooling tubing 107. In some embodiments, main unit 103 may include spooling mechanism 1501 to spool tubing 107 into and/or out of lower compartment 211. Spooling mechanism 1501 may be activated by a user (e.g., using a switch on spooling mechanism 1501). Other methods for activating spooling mechanism 1501 are also contemplated (e.g., button activated). In some embodiments, spooling mechanism 1501 may be driven by an internal spring. For example, the internal spring may absorb energy as the internal spring is wound (e.g., as tubing 107 is pulled out of main unit 103) and which then rotates spooling mechanism 1501 in the opposite direction to wind up tubing 107 as the internal spring returns to its unstressed state when the user releases a pulling force on tubing 107. In some embodiments, spooling mechanism 1501 may be driven by a user-activated handle. In some embodiments, the spooling mechanism may be driven by a small motor and may be user activated via buttons (other user activation mechanisms and other user activation mechanism locations are also contemplated) on enclosed bathtub heat exchanger 421. In this embodiment, a mechanism may be included in positioning component 421 that detects when positioning component 421 is attached to the side of the bathtub (or otherwise attached) and may deactivate one or more user-activated switches (or other controls). Deactivating the user-activated switches while positioning component 421 is attached may prevent spooling of tubing 107 in possibly unsafe situations (e.g., spooling tubing 107 while attachment mechanism 501 is attached to bathtub 111). Other operating mechanisms are also contemplated.

[0085] FIGs. 16a-b illustrate an embodiment of rotatable housing 1600 for spooling mechanism 1501. In some embodiments, the end of tubing 107 may be coupled to warm inlet nozzle 1601 and cool inlet nozzle 1603 at the center of spooling mechanism 1501. Interior compartment 1605 may provide a pathway for warm fluid (e.g., outgoing fluid 419) and interior compartment 1607 may provide a pathway for cool fluid (e.g., incoming fluid 419). Warm fluid may flow through interior compartment 1607 from inlet nozzle 1609, and cool fluid may flow from cool inlet nozzle 1603 through interior compartment 1607 (which may wrap around interior compartment 1605) to cool inlet nozzle 1611. Rotatable housing 1600 may include fixed portion 1617 and rotating portion 1615. In some embodiments, power and control lines 1613a may enter the side of fixed portion 1617 and may transfer power/control signals to respective power and control lines 1613b (e.g., extruded in tubing 107) through slip ring interface 1619 including slip rings 1621 and corresponding slip ring conductive tracks 1623. In some embodiments, internal o-rings 1625 may maintain a seal to prevent fluid from leaking out of the interior of rotatable housing 1600 while allowing rotating portion 1615 to rotate relative to fixed portion 1617. Inlet nozzle 1609 may be coupled to outlet 913 (e.g., directly or through a tube) and inlet nozzle 1611 may be coupled to inlet valve 431 (see FIG. 9) (e.g., directly or through a tube). Other coupling methods are also contemplated.

[0086] FIG. 17 illustrates a flowchart of an embodiment of a method for using bathtub heating system 100. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0087] At 1701, a user may take bathtub heater 105 out of the main unit box (e.g., lower compartment 211) and may couple bathtub heater 105 to bathtub 111. In some embodiments, the user may couple bathtub heater 105 to bathtub 111 by unfolding bathtub heater 105 and placing suction cup 505 in contact with the bathtub wall and applying pressure to engage suction cup 505. In some embodiments, the user may also lower suction cup arm 507. The user may also place suction cups 703 of tube clip 513 in contact with the outer wall of bathtub 111 and may apply pressure to engage suction cups 703 (the user may also lower lever arms 701). The user may further insert tubing 107 (coupled to bathtub heater 105) into tube clip 513. In some embodiments, assembly by the user may not be needed (e.g., see embodiment shown in FIGs. 20a-b).

[0088] At 1703, the user may activate bathtub heating system 100. For example, the user may press on/off switch 1419, press a button, etc. In some embodiments, bathtub heating system 100 may automatically activate when it detects sufficient bathtub fluid 104 to operate (e.g., no user interaction may be required).

[0089] At 1705, bathtub heating system 100 may determine if the fluid level of bathtub 111 is sufficient for operating. For example, a fluid level detection sensor 1407 (see also fluid level sensor 2051 in FIGs. 20a-b) may determine, for example, if bathtub fluid 104 in bathtub 111 covers heat exchanger element 305. The fluid level sensor may be an electrical sensor, a pressure sensor, etc. used for detecting if a bathtub fluid is present proximate to the sensor. In some embodiments, temperature sensors (e.g., temperatures sensors 2005a,b in FIGs. 20a-b) may be used to detect the presence of bathtub fluid 104 in bathtub 111 above a minimum operating level. For example, the temperature of bathtub fluid 104 may be detected by temperature sensor 2005a as the fluid level rises above temperature sensor 2005a. In some embodiments, bathtub heating system 100 may provide an indication to the user (e.g., a blue LED may be pulsed to indicate bathtub heating system 100 is waiting for the fluid level to reach a sufficient level or a steady blue LED indicating the fluid level is sufficient). Other indications are also contemplated. The user may add bathtub fluid 104 as needed.

[0090] At 1707, bathtub heating system 100 may detect the temperature of bathtub fluid 104. In some embodiments, bathtub heating system 100 may monitor the temperature of bathtub fluid 104 (e.g., using temperature sensors 1403c,d) through an initial temperature adjustment period to determine when the temperature has stabilized (e.g., remained near constant over a predetermined duration such as 20 seconds). The initial temperature adjustment period may also correspond to a period during which a detected temperature change rate of the bathtub fluid exceeds a threshold (e.g., +/- 2 degrees F in a time range of 1-2 seconds). Other thresholds are also contemplated. In some embodiments, the initial temperature adjustment period may be a fixed time (e.g., 3 minutes as indicated by a timer presented to the user). At the conclusion of the fixed time, the detected temperature may become the control set point temperature to maintain by the bathtub heating system. Other time periods are also contemplated. In some embodiments, a user may press a button (or other user control) to signal when the user has bathtub fluid 104 at the desired temperature to maintain. Waiting for the temperature to stabilize may allow the bathtub fluid temperature to be adjusted by the user (e.g., by adding/draining hot/cold bathtub fluid 104) and for bathtub fluid 104 to sufficiently mix. In some embodiments, a slight pink LED may activate to show the user bathtub heating system 100 is waiting for the temperature to stabilize. Other indicators are also contemplated. In some embodiments, the bathtub heating system may not detect a temperature of the bathtub fluid 104.

[0091] At 1709, bathtub heating system 100 may maintain the detected bathtub fluid temperature. In some embodiments, a solid pink LED may be activated to indicate the current temperature is being maintained. Other indicators are also contemplated. In some embodiments, as bathtub heating system 100 detects a temperature drop, bathtub heating system 100 may increase the temperature and/or flow rate of fluid 419. In some embodiments, if a detected temperature change is greater than a predetermined threshold (e.g., 2 degrees F), bathtub heating system 100 may indicate to the user that a new temperature is being detected (e.g., through a slight pink LED) and then the new temperature is being maintained (e.g., through a solid pink LED). For example, the user may change the temperature of bathtub fluid 104 during the bath (e.g., by adding/draining hot/cold bathtub fluid 104). In some embodiments, the temperature change threshold (for which a new temperature will be detected and maintained) may be set by the user (e.g., to increase/decrease the sensitivity of bathtub heating system 100). This new temperature (i.e., second bathtub fluid temperature) may be detected during a subsequent temperature adjustment period (i.e., subsequent to the initial temperature adjustment period). In some embodiments, a predetermined power may be applied to the heating element to approximately maintain the temperature of the bathtub fluid without detecting a temperature of the bathtub fluid.

[0092] In some embodiments, bathtub heating system 100 may cycle on and off during use (e.g., while providing heat). The bathtub heating system 100 may continue to monitor temperature continuously (e.g., even during off periods). If the heating element is off and bathtub heating system 100 detects a temperature increase, the temperature increase may be attributed to a user water change. Further, if the temperature stays constant after the detected change, the change may be attributed to a water change. If the heating element is on and the temperature of bathing fluid 104 is increasing more than a rate of approximately 0.5 degrees F in approximately a range of 2-3 minutes (and the temperature does not increase when the heating element is off) the temperature change may be attributed to a low water level (e.g., below the minimum operating line). Other rates and ranges for the rates are also contemplated. In some embodiments, a predetermined amount of heat may be provided to approximately maintain a constant temperature without measuring a temperature associated with the bathing fluid. For example, a bathtub fluid 104 may be predetermined to lose approximately 1 degree F every 17 minutes without heat applied and a heat calculation may be performed to determine how much heat to provide the bathtub fluid 104 to offset the loss to maintain approximately a constant temperature. Other predetermined losses are also contemplated. For example, a different bathtub in a different environment may experience a loss of 2 degrees F every 10 minutes.

[0093] At 1711, the user may deactivate bathtub heating system 100 and may place bathtub heater 105 back in the main unit box (e.g., lower compartment 211). In some embodiments, the user may deactivate bathtub heating system 100 by pressing on/off switch 1419, press a button, etc. In some embodiments, bathtub heating system 100 may automatically deactivate when the fluid level detection sensor 1407 detects the fluid level has fallen below a predetermined level (e.g., due to the user draining bathtub fluid 104 and/or lifting bathtub heater 105 out of bathtub fluid 104). In some embodiments, the user may disengage suction cup 505 by lifting up on suction cup arm 507 and may disengage suction cups 703 by lifting up on suction cup arms 701.

[0094] In various embodiments, bathtub heating system 100 may have other configurations. For example, bathtub heating system 100 may incorporated into bathtub 111. For example, as seen in FIGs. 18a-c, main unit 103 may be incorporated into bathtub 111 and the bathtub heater components may be integrated with the bathtub walls. FIGs. 18a-d illustrate cross-sections of bathtub 111 with various configurations of bathtub heating system 100.

[0095] FIG. 18a illustrates an embodiment of main unit 103 configured inside the bathtub walls and coupled to heat exchangers that are coupled to the bathtub walls. While main unit 103 is shown below bathtub 111, other locations of main unit 103 are also contemplated (e.g., next to a side wall of bathtub 111, in front of bathtub 111, behind bathtub 111, in a wall located next to bathtub 111, etc.). Main unit 103 may include heating element 425 and the pump (e.g., thermal expansion pump 1201). Fluid 419 may be heated by heating element 425 in main unit 103 and pumped through tubing 1801 (which may be dual chambered tubing) to and from a heat exchanger element 305 mounted in side units 1803 (e.g., through screws or other fasteners). Bathtub fluid 104 may flow through screens 1805 and into thermal contact with heat exchanger elements 305 in side units 1803. Driving mechanisms 411 may facilitate bathtub fluid flow over heat exchanger elements 305 and back and forth to bathtub 111. In some embodiments, screens 1805 may be made of plastic or another insulating material. Other configurations and materials for screens 1805 are also contemplated (e.g., screens 1805 may be flush with the bathtub walls). In some embodiments, side units 1803 may also be made of plastic or another material. In some embodiments, the bathtub walls between screens 1805 and side units 1803 may have apertures to facilitate bathtub fluid flow between side units 1803 and screens 1805. In some embodiments, screen 1805 may include a filter to filter out debris, etc. In some embodiments, the filter may be replaceable and/or cleanable.

[0096] FIG. 18b illustrates an embodiment of main unit 103 configured inside the bathtub walls to receive bathtub fluid 104 through tubes 1801 from screens 1805. Bathtub fluid 104 may be pumped to main unit 103, heated, and pumped back through tubes 1801 back to bathtub 111. In some embodiments, bathtub fluid 104 may be pumped to main unit 103 through tube 1801 on one side of bathtub 111 and back to bathtub 111 through tube 1801 on the opposing side of main unit 103. In some embodiments, tubes 1801 on both sides of main unit 103 may pump fluid to and from respective sides of bathtub 111. In some embodiments, a tube chamber pulling fluid from bathtub 111 may be spaced away from the tube chamber delivering heated fluid to bathtub 111 (e.g., by spacing apart the respective tube chambers in screens 1805).

[0097] FIG. 18c illustrates an embodiment of main unit 103 coupled to an inside of bathtub 111. In some embodiments, main unit 103 may be coupled to the inside of bathtub 111 by an over side clip/mounting bracket 1807 and/or suction cups between main unit 103 and bathtub 111. Other coupling mechanisms are also contemplated. Main unit 103 may directly heat bathtub fluid 104 which may flow to/from main unit 103 through screen 1805. In some embodiments, main unit 103 may indirectly heat bathtub fluid 104 by heating a fluid pumped to heat exchanger 305 that is in thermal contact with bathtub fluid 104.

[0098] In some embodiments, bathtub heating system 100 may include an externally attached main unit 103 as seen in FIG. 18d. In some embodiments, main unit 103 may be coupled to the outside of bathtub 111 by an over side clip/mounting bracket 1807 and/or suction cups between main unit 103 and/or tube 1809 and bathtub 111. Other coupling mechanisms are also contemplated. Main unit 103 may directly heat bathtub fluid 104 which may flow to/from main unit 103 through tube 1809 (which may be a dual chamber tube). In some embodiments, bathtub fluid 104 may be filtered through a screen/filter prior to entering tube 1809 and/or may be filtered prior to entering main unit 103. In some embodiments, the filters may be replaceable and/or cleanable. In some embodiments, main unit 103 may indirectly heat bathtub fluid 104 by heating a fluid pumped to heat exchanger 305 (inside main unit 103) that is in thermal contact with bathtub fluid 104. In some embodiments, an AC power cord may deliver power to main unit 103 shown in FIGs. 18a-d. Other power sources are also contemplated. In some embodiments, bathtub heating system 100 may maintain Underwriters Laboratories (UL) and Safety requirements and may give the user extra perception of being safe (e.g., by having main unit 103 located away from bathtub fluid 104).

[0099] In some embodiments, bathtub heating system 100 may be integrated into a smaller tub structure (e.g., an baby bathtub as seen in FIGs. 19a-b). In some embodiments, main unit 103 may be remotely located from bathtub 111. In some embodiments, fluid 419 may be heated by heating element 425, pumped through tube 107 to heat exchanger element 305 in side compartment 1901 and placed in thermal contact with bathtub fluid 104. Bathtub fluid 104 may flow through screen 1903 and may be directed by driving mechanism 411 on heat exchanger element 305. In some embodiments, fluid 419 may be bathtub fluid 104 (which may be pumped to main unit 103 through tube 107, heated, and then returned to bathtub 111). The inlet of the receiving chamber of tube 107 may be on one side of screen 1903 and the outlet of the delivery chamber of tube 107 may be on the other side of screen 1903. Other tube configurations are also contemplated. In some embodiments, screen 1903 may include a filter to filter bathtub fluid 104 prior to bathtub fluid 104 being pumped to main unit 103. In some embodiments, main unit 103 may be integrated or coupled to baby bathtub 111 (e.g., using a configuration shown in FIGs. 18a-d). In some embodiments, screen 1903 may be made of plastic to a prevent contact between a user of bathtub 111 and heat exchanger element 305. In some embodiments, bathtub heating system 100 may be configured for safer operating levels when operating with baby bathtub 111. For example, bathtub heating system 100 may have a lower maximum temperature limit for the threshold used for bathtub fluid 104 (e.g., 105 degrees F). Other temperature limits are also contemplated. Bathtub heating system 100 may also have stricter limits on other safety thresholds and comparisons to expected operating models that may trigger bathtub heating system 100 to shut down (e.g., bathtub heating system 100 may be more sensitive to errors). In some embodiments, main unit 103 and other components of bathtub heating system 100 for baby bathtub 111 may be sealed to prevent a user (e.g., a toddler) from accessing the internal components. In some embodiments, scents, oils, etc. may not be provided or used with bathtub heating system 100 for baby bathtub 111. Heat exchanger element 305 may also be configured to prevent heated bathtub fluid 104 flowing out of screen 1903 from exceeding a safe temperature (e.g., by spreading bathtub fluid 104 over a larger surface area of heat exchanger element 305 to maximize energy absorption at a lower temperature (e.g., by adding energy to a greater volume of bathtub fluid 104).

[00100] FIGs. 20a-c illustrate another embodiment of bathtub heating system 100. In some embodiments, bathtub heating system 100 may include heating element 2003 wrapped around a portion of bathtub 111. Heating element 2003 may include a heating wire wrapped at intervals (e.g., approximately in a range of 4-8 inches (such as 6 inches)) around at least a portion of bathtub 111 (e.g., around the bathtub bottom 2015 and sides 2013a-d). Other intervals are also contemplated (e.g., less than 1 inch, 2 inches, etc). Other heating elements are also contemplated. For example, the heating element may include a surface resistant material (such as a sprayed-on carbon film) that heats when conveying a current, hot air or water may be circulated on the outside of bathtub 111 to heat bathtub 111, etc. The heating element may be configured to evenly heat the bathtub fluid 104 in the bathtub 111 (e.g,. without circulating the bathtub fluid 104). In some embodiments, insulation may be included around the sides 2013a-d and/or bottom 2015 of bathtub 111 (e.g., to prevent user contact with heating element 2003).

[00101] In various embodiments, bathtub heating system 100 may also include one or more sensors (e.g., temperature sensors 2005a,b). Sensors may be located on the outside of bathtub 111 (e.g., temperature sensor 2005a near the top of the bathtub 111 and temperature sensor 2005b near a bottom 2015 of bathtub 111 (e.g., at an area without heating element 2003), a fluid level sensor 2051 near a minimum fluid line for operation, etc). Other sensors are also contemplated (e.g., pressure sensors, pH sensors, water detection sensors, etc). In some embodiments, bathtub heating system 100 may further include a control system (e.g., including a microprocessor in control box 2009) that accesses temperature readings from temperature sensors 2005a,b and applies variable power to heating element 2003.

[00102] FIG. 20c illustrates an embodiment of a heating element configuration on the bathtub 111. The bathtub 111 may include 4 loops (e.g., loops 2050a-d) of heating wire (e.g., 28 gauge Nichrome wire) that each start at the front of the bathtub 111, wrap around the sides and back of the bathtub 111 and loop at the front of the bathtub 111 (see FIG. 20c). Other numbers and configurations of loops 2050 are also contemplated. In some embodiments, each loop may include a wire approximately 25 feet long. Other lengths are also contemplated (e.g., shorter or longer loops for shorter or longer bathtubs). Other wire type is also contemplated (e.g., while 28 gauge Nichrome wire may have a resistance of approximately 4.3 ohms/foot (and provide approximately 5 watts per linear foot), other gauge wire and power is also contemplated). Additional loops of wire may be provided for the bottom of the bathtub 111 (e.g., see bottom configuration in FIG. 20a). The configuration shown in FIG. 20c with the additional loops on the bottom may provide a power approximately in a range of approximately 700-1100 watts (e.g., 900 watts). Other power levels are also contemplated. In some embodiments, the wire loops on the bottom of the bathtub 111 may also be approximately 25 foot long (other lengths are also contemplated). In some embodiments, the wires of the loops may be spaced approximately 1 inch from each other and from other wire loops. Other spacings are also contemplated (e.g., 0.5 inches, 2 inches, etc).

[00103] In some embodiments, a control box 2009 may be coupled to the loops of wire to provide and control the electrical current supplied to the heating elements. In some embodiments, each loop may be controlled separately (e.g., in some embodiments, separate temperature sensors may be placed in the proximity of each loop and the current supplied to each respective loop may be varied according to the temperature detected (e.g., to keep a uniform temperature over the surface of the bathtub 111). In some embodiments, uniform power may be supplied to the heating elements without separately controlling the power level to each heating element.

[00104] In some embodiments, there may be no user controls, and bathtub heating system 100 may maintain a temperature of bathtub fluid 104 in bathtub 111. For example, at the start of a bath, the bathtub fluid temperature may be detected by temperature sensor 2005 (the initial temperature (e.g., after the temperature stabilizes) may be the control set point temperature). The control set point temperature may be maintained during the bath. In some embodiments, a user may not turn on/off bathtub heating system 100. For example, a temperature sensor 2005a and/or fluid level sensor 2051 may be placed near a minimum fluid line for operation of the bathtub heating system 100. When the user fills bathtub 111 up to temperature sensor 2005a and/or fluid level sensor 2051 (e.g., the temperature of bathtub fluid 104 may be detected by temperature sensor 2005a and/or the fluid level may be detected by the fluid level sensor 2051 as the fluid level rises above temperature sensor 2005a), bathtub heating system 100 may automatically turn on. When the user drains bathtub 111 below the level of upper temperature sensor 2005a (and/or fluid level sensor 2051), bathtub heating system 100 may automatically turn off. A rate of change in detected temperature may indicate the presence or absence of bathtub fluid 104. For example, during operation, if the temperature detected at temperature sensor 2005a is increasing quickly (e.g., above a range of approximately 1-2 degrees F per minute), bathtub heating system 100 may determine that there is no bathtub fluid 104 in the region of temperature sensor 2005a detecting the rapid change (which may be due to heating element 2003 heating bathtub 111 without heat exchange to bathtub fluid 104). If the temperature is detected as changing within the range of approximately 1-2 degrees F per minute, bathtub heating system 100 may determine that bathtub fluid 104 is over the level of temperature sensor 2005a. In some embodiments, two temperature sensors 2005a,b may be used (temperature sensor 2005b at a lower location in bathtub 111 and temperature sensor 2005a at an upper location in bathtub 111) to determine an average temperature of bathtub fluid 104 and/or to monitor the temperature of bathtub fluid 104 at multiple locations in bathtub 111.

[00105] In some embodiments, if the user wants to increase the temperature of bathtub fluid 104, he/she may add warmer bathtub fluid 104 (and/or drain out cooler bathtub fluid 104) to bathtub 111 to increase the average bathtub fluid temperature. In some embodiments, the average bathtub fluid temperature may be determined as the average of the temperatures detected by temperature sensors 2004a and 2005b. If the user wants a lower temperature bathtub fluid 104 he/she may add cooler bathtub fluid 104 (and/or drain out warmer bathtub fluid 104) to decrease the average fluid temperature. In some embodiments, a change in the temperature of one or more temperature sensors 2005a,b above a threshold rate of change may reset the control set point temperature. In some embodiments, bathtub heating system 100 may remain off until both temperature sensors 2005a,b are above a threshold (e.g., a temperature between 80-100 degrees F (such as 90 F)). The temperature may raise above the threshold when the user fills bathtub 111 with warm bathtub fluid 104. In some embodiments, if either temperature sensor 2005a,b indicates a temperature below the threshold (e.g., below 90 F) and/or if the temperature is increasing above a threshold rate (e.g., above a range of approximately 1-2 degrees F per minute) bathtub heating system 100 may turn off. In some embodiments, bathtub heating system 100 may also use an upper threshold approximately in a range of 100-120 degrees F (e.g., if either temperature sensor 2005a,b indicates a temperature above approximately 104 F bathtub heating system 100 may turn off).

[00106] In some embodiments, when the user begins to drain bathtub 111, upper temperature sensor 2005a may no longer be covered with bathtub fluid 104. If the temperature of upper temperature sensor 2005a increases rapidly while the heating power is applied (e.g., above a range of approximately 1-2 degrees F per minute) and/or if the temperature of upper temperature sensor 2005a differs by more than a difference approximately in range of 1-4 degrees F (e.g., 2.5 degrees F) from lower temperature sensor 2005b bathtub heating system 100 may turn off. Either of these conditions may occur when no bathtub fluid 104 covers upper temperature sensor 2005a. Increasing rapidly may include a rate of increase that would occur if no bathtub fluid 104 covers temperature sensor 2005 (and bathtub 111 is still being heated by the heating element). In some embodiments, bathtub heating system 100 may include only one temperature sensor (e.g., upper temperature sensor 2005a) that may detect the temperature to be maintained and detect if the bathtub fluid 104 is above a minimum operating line. Other numbers of temperature sensors are also contemplated. In some embodiments, bathtub heating system 100 may use a fluid level sensor 2051 to detect the presence of fluid (e.g., an electrical sensor, a mechanical sensor, pressure switch, etc).

[00107] In some embodiments, bathtub heating system 100 may not include a temperature sensor (e.g., bathtub heating system 100 may apply power when bathtub fluid 104 is detected through, for example, fluid level sensor 2051). In some embodiments, a power level for the heating element to maintain a temperature of a bathtub fluid in the bathtub 111 may be predetermined such that when fluid is detected at the fluid level sensor, the predetermined power may be applied to the heating element to approximately maintain the temperature. For example, bathtub heating system 100 may apply approximately 600 watts as long as bathtub fluid 104 is detected. Approximately maintaining a temperature of the bathtub fluid may include maintaining the temperature within a range of +/- 1 degree F over an hour. Other ranges for approximately maintaining a temperature are also contemplated (e.g., within a range of +/- 5 degrees F over an hour, etc).

[00108] In some embodiments, the bathtub heating system may decrease the temperature of the bathtub fluid over time (e.g., at a default or user specified rate and/or time). For example, the bathtub heating system may allow the temperature of the bathtub fluid to drop 0.5 to 2 degrees F over 0.5 hours. Other cooling profiles are also contemplated (these may be user selected/entered or system determined). In some embodiments, the cooling profile may allow a user to stay in the bathtub longer without overheating.

[00109] In some embodiments, bathtub heating system 100 may include user controls. For example, bathtub heating system 100 may include an on/off switch and/or a temperature control to allow the user to increase or decrease the temperature of bathtub fluid 104. In some embodiments, a sensitivity control may be included to allow the user to adjust how quickly bathtub heating system 100 adjusts to and maintains new temperatures (e.g., the control may be set to a less sensitive setting to allow the user more time to adjust the bathtub temperature by adding/removing bathtub fluid 104 before bathtub heating system 100 begins attempting to maintain a detected temperature). Other user controls are also contemplated.

[00110] FIG. 21 illustrates an embodiment of heating element 2003. In some embodiments, heating element 2003 may include insulated nichrome wire 2101 (e.g., nichrome ribbon) at intervals around bathtub 111 (and/or along the bottom of bathtub 111). For example the wire may be approximately in a range of 30 to 22 gauge Nichrome 60 or Nichrome 80 wire. Other wire materials are also contemplated (e.g., copper wire, aluminum wire, etc). In some embodiments, wire 2101 may be applied to the inside of sheet 2105a of insulating material (e.g., fiberglass) to more evenly spread the heat from wire 2101 along sheet 2105a for even heating of bathtub fluid 104. In some embodiments, wire 2101 may be held in place on sheet 2105a using tape 2103 (e.g., aluminum tape, Kapton™ tape, Teflon™, etc). For example, 5 mil (mil = 0.001 inches), 6 mil, or 9 mil thick Tefzel™ may be used to coat wire 2101. Other fasteners are also contemplated (e.g., adhesive, molding a polymer around wire 2101, etc). In one embodiment, 3/32 inch by 0.0045 inch Nichrome ribbon insulated with 2.7 mil Kapton™ tape may be secured to first sheet 2105a and/or bathtub 111 with 2.7 mil aluminum tape. Other dimensions are also contemplated. For example, dimensions of Nichrome ribbon may be approximately in a range of 1/32 to 12/32 by 0.001 to 0.01 inch insulated with 1 to 4.5 mil Kapton™ tape. In some embodiments, wire 2101 may be embedded in sheet 2105a (e.g., sheet 2105a may be formed (e.g., molded) around wire 2101. Second sheet 2105b may be secured over first sheet 2101a with wire 2101 secured between two sheets 2105a,b. Two sheets 2101a,b may be fused together with heat or coupled together using adhesive. Other coupling techniques are also contemplated. In some embodiments, the Nichrome ribbon may be crimped to be received into a power source (e.g., on control box 2009). In some embodiments, the Nichrome ribbon may be bent (e.g., at the corners of bathtub 111 and/or when the Nichrome ribbon changes direction, for example, at sites 2011a,b). At the bends, additional insulation may be used. For example, an additional layer of Kapton™ tape may be placed under and over the bend.

[00111] Two sheets 2105a,b may form a portion of bathtub 111 and/or may be secured to a portion of bathtub 111. In some embodiments, second sheet 2101b may be used to fuse first sheet 2101a to a side and/or bottom 2015 of bathtub 111. For example, first sheet 2101a and/or side/bottom of bathtub 111 may be fiberglass (or, for example, metal) and second sheet 2101b may be a material that may be melted (e.g., a polymer) to fuse first sheet 2101a to the side/bottom of bathtub 111. In some embodiments, second sheet 2101b may include holes to allow better contact between the wires and/or tape and the side/botttom of bathtub 111. Other layers and materials may also be used. For example, a layer of Styrofoam™ board may be used along the outside of first sheet 2105a to further insulate bathtub heating system 100.

[00112] In some embodiments, wire 2101 may be wrapped around the sides 2013a-d of bathtub 111 (e.g., through sheets 2105a,b or directly to bathtub 111) and apply heat in a range of approximately 50-60% (of total heat applied to bathtub 111) to the sides 2013a-d of bathtub 111. Other ranges are also contemplated (e.g., 70-90%). Applying the heating element over a greater surface area may increase heating uniformity and reduce hot/cold spots in bathtub fluid 104.

Wire 2101 may also be applied to the bottom 2015 of bathtub 111 (e.g., applying heat in a range of approximately 40-50% (of total heat applied to bathtub 111) to the bottom 2015). Other ranges for the bottom 2015 are also contemplated (e.g., 70-90%). In some embodiments, a greater percentage of heat may be applied to bottom 2015 of bathtub 111 than to the sides of bathtub 111 to increase convective heat flow in bathtub fluid 104.

[00113] In some embodiments, wire 2101 may provide power at less than approximately 10 watts/foot. Other power density is also contemplated (e.g., greater than 10 watts/foot, in a range of 5 to 15 watts/foot, etc). In some embodiments, wire 2101 may provide a resistance approximately in a range of 1-4 ohms per foot (e.g., 2.5 ohms per foot). In an embodiment, approximately 100 feet of wire on bathtub 111 may provide approximately 1000 watts of heating (e.g., 100 feet * 10 watts/foot = 1000 watts). In some embodiments, bathtub fluid 104 may lose approximately 300 watts of heat to the air and approximately 700 watts through the bathtub 111 and other sources. The 1000 watts may offset this loss to hold the temperature of bathtub fluid 104 steady. Other heat loss and heat application wattages are also contemplated (e.g., the heat loss from bathtub fluid 104 may be greater in a colder environment (such as in a bathtub located outdoors in a cold environment) and, therefore, greater heat may be needed from bathtub heating system 100 to offset the heat loss). In some embodiments, heat loss may be less through the bathtub 104 (e.g., if bathtub 111 is heavily insulated, total heat loss may be approximately 300 watts). In some embodiments, the heat applied by bathtub heating system 100 may be variable to hold the temperature approximately steady. For example, bathtub heating system 100 may apply more or less heat according to a detected temperature and/or rate of temperature change (e.g., detected through temperature sensors 2005a,b). In some embodiments, more or less heat may be applied to increase or decrease the temperature (e.g., as requested through user input).

[00114] In some embodiments, wire 2101 may be continuous around the sides 2013a-d and the bottom 2015 of bathtub 111. In some embodiments, there may be two or more zones of wires (e.g., separate wires). For example, there may be one zone on the bottom 2015 of bathtub 111 and one zone around the sides 2013a-d of bathtub 111. Different levels of heating may be applied to each zone. For example, if lower temperature sensor 2005b senses a drop in temperature, a zone of heating element 2003 along the bottom 2015 of bathtub 111 may receive more energy to apply more heat to the lower portion of bathtub fluid 104. In some embodiments, wire 2101 may include series and parallel path portions on bathtub 111. As an example, approximately a 25 foot section of approximately 3/32 inch Nichrome ribbon wire (with a resistance of approximately 32.9 ohms) may generate approximately 437 watts at 120 volts and may be used with a second approximately 45 foot section of Nichrome ribbon with a resistance of approximately 67.3 ohms operating at approximately 214 watts. In another example, approximately 430 watts may be provided through approximately a 4 inch horizontal loop (e.g., formed of two strands of Nichrome ribbon) around the sides 2013a-d of bathtub 111 and approximately 213 watts on the bottom 2015 of bathtub 111 (e.g., with approximately 12 rows of Nichrome ribbon). In some embodiments, each loop around the sides 2013a-d of bathtub 111 may be a separate loop electrically coupled to control box 2009. In some embodiments, one helical loop may include several passes around the sides 2013a-d of bathtub 111.

[00115] FIG. 22 illustrates an embodiment of separating sidewall 2201 to install heating element 2003 to the side (and/or bottom) of bathtub 111. In some embodiments, heating element 2003 may be applied to bathtub 111 by accessing a bottom and/or side of bathtub 111 (e.g., by removing sidewall 2201). For example, wire 2101 may be taped (e.g., using tape 2103) to the sides and/or bottom of bathtub 111 at intervals. Sidewall 2201 may then be replaced to prevent user contact with heating element 2003 during operation. In some embodiments, heating element 2003, control box 2009, temperature sensor 2005a,b, etc. may be provided to the user in the form of a kit that the user may install on bathtub 111. In some embodiments, heating element 2003, control box 2009, temperature sensor 2005a,b, etc. may be formed into bathtub 111 as a pre-installed unit. In some embodiments, bathtub heating system 100 may not have moving parts and may operate very quietly.

[00116] FIG. 23a-b illustrate an electrical schematic of the bathtub heating system 100, according to an embodiment. It is to be noted that the values provided in FIGs. 23a-b (e.g., resistance, capacitance, inductor values, etc.) are examples of one embodiment. Other values and configurations are also contemplated. In some embodiments, a microcontroller unit (MCU) (e.g., a PIC18F242) (i.e., master controller 2301) may be used along with an oscillator (OSC) (e.g., a 20Mhz crystal oscillator (200ns instruction clock)) to control the bathtub heating system 100. Further, an I2C communication medium may be used to communicate with the temperature sensors 2005 (the temperature sensors 2005 may be slaves to the master controller 2301 and may use, for example, a 100Khz clock). In some embodiments, a UART (Universal Asynchronous Receiver-Transmitter) may be used as a debug port and may use compilers such as putch, getch, and printf routines 57600 baud, N81. A watch dog timer (WDT) may also be used (e.g., with approximately a 4 second timeout to time once each loop through master controller 2301). Interrupts may also be used (e.g., INT0 may be used for sensing zero crossing of AC power), TMRO may be used as a delay before turning on the TRIAC after a zero crossing, UART receive, and UART transmit). Timers may also be used (e.g., Timer 0 may be used as a delay before turning on the TRIAC after each half cycle). The timer may be configured as a 16 bit timer. After each zero crossing, a number may be generated to load TMR0 based on a desired duty cycle. Upon overflow, the TRIAC may be turned on. In some embodiments, another timer may be used for an approximate 8.33ms main loop synch timer auto-reloaded for 8.33ms timeout when no long term timing error interrupt flag is checked in main loop to synch to, but interrupts may not be used (other times and timeouts are also contemplated). In some embodiments, a minimum loop interval may be approximately 8.33ms (other times are also contemplated). In some embodiments, master controller 2301 tasks may be called from master controller 2301 every 5 ms (other times are also contemplated). In some embodiments, the task interval may be approximately 50ms (e.g., with a 6x main loop) (other times and loops are also contemplated). In some embodiments, tasks may be called from master controller 2301 every 50 ms (other times are also contemplated). Some code samples are provided below (these samples are to be taken as exemplary only – other coding may also be used).

[00117] Global Variables

Uint8 - operation_mode (MANUAL_MODE, NORMAL_MODE)

Uint8 - operation_state (STATE_OFF, STATE_MEASURE, STATE_CONTROL, STATE_COOLDOWN, STATE_TURN_OFF_DELAY, STATE_DETECT_WATER_LOSS)

Uint16 - heater_setpoint_temp_degf_x10 (target temperature)

[00118] Interrupt Service Routines

UART TX and RX (Used for debug port)

TMR0 (Used to turn on the TRIAC after a delay each half cycle of the AC)

Init Ports (This function initializes the IO ports (port direction, port input / output type, pull-ups, analog selection functions, etc.). It also places all IO into the default safe state.

[00119] Main Tasks Definitions

These functions may be called from master controller 2301 every 8.33ms (other times are also contemplated)

Service Heater

Tasks Definitions

Service Process (This function is the high level application that controls the overall behavior. See the flowchart in FIG. 24)

```
Enum {
STATE_OFF=0;
STATE_MEAURE,
STATE_CONTROL,
STATE_COOL_DOWN,
STATE_TURN_OFF_DELAY,
STATE_DETECT_WATER_LOSS
}
switch (app_state)
{
        default:
        case APP_OFF:
                heating_enabled = FALSE;
if (temperature_too_low == FALSE)
{
app_state = APP_MEASURE;
count = 0;
}
break;

case APP_MEASURE:
        heating_enabled = FALSE;
        if (count < MEASURE_TIME)
        {
                heater_setpoint_temp_degc_x100 = avg_temp_degc_x100;
                count = 0;
                app_state = APP_CONTROL;
        }
        Else count++
        break;

case APP_CONTROL:
        heating_enabled = TRUE;
```

```
        count++;
        if (temperature_too_high)
                app_state = APP_COOL_DOWN;
        else if (temperature_too_low)
                app_state = APP_TURN_OFF_DELAY;
        else if (rate_of_change_too_fast)
                app_state = APP_MEASURE;
        else if (count == WATER_LOSS_CHECK_DELAY)
                app_state = APP_DETECT_WATER_LOSS;
        break;

case APP_COOL_DOWN:
        heating_enabled = FALSE;
        if (!temperature_too_high)
        {
                app_state = APP_TURN_OFF_DELAY;
                count = 0;
        }
        break;

case APP_TURN_OFF_DELAY:
        if (++count == TURN_OFF_DELAY)
{
        count = 0;
        app_state = APP_OFF;
}
break;

case APP_DETECT_WATER_LOSS:
        heating_enabled = FALSE;
        count++;
        if (avg_temp_change_degc_x100 > 5)
        {
        App_state = APP_TURN_OFF_DELAY;
```

```
            Count = 0;
        }
        Else if (count == WATER_LOSS_TIMEOUT_DELAY)
        {
            App_state = APP_CONTROL;
            Count = 0;
        }
        Break;
}
```

In some embodiments, a health LED (light emitting diode) may blink at approximately a 1Hz rate (other rates are also contemplated) when the bathtub heating system 100 is not in an idle state and may be off when the bathtub heating system 100 is in the idle state. In some embodiments, the duty cycle may be 90% when heating and 10% when not heating (other duty cycles are also contemplated).

OFF	state = STATE_OFF
1Hz 10%	State = STATE_CONTROL
1Hz 90%	Any other state

[00120] In some embodiments, a service debug port may be available. It may check to see if any new messages have been received. If they have and correspond to a valid command, that command may be executed. Example commands are provided below (other commands and command formats are also contemplated):

VER (may be used to display a firmware version and build date) (in some embodiments, may be available in auto mode);

AUTO (may be used to toggle the operation mode of the bathtub 111 between automatic and manual) (in some embodiments, may be available in auto mode);

SP=x (may be used to set the set point temperature for the heater in deg Fahrenheit (F) x 10) (in some embodiments, may not be available during auto mode);

HTRT=x (may be used to set the duty cycle value for the top heater, where x may be 0 to 120 (other values of x are also contemplated) (in some embodiments, may not be available during auto mode);

HTRT? (may be used to display the top heater duty cycle) (in some embodiments, may be available in auto mode);

HTRB=x (may be used to set the duty cycle value for the bottom heater) (in some embodiments, may not be available during auto mode);

HTRB? (may be used to display the bottom heater duty cycle) (in some embodiments, may be available in auto mode);

TEMP (may be used to toggle temperature monitoring on and off; when enabled, the sensor temperatures and heater duty cycles may be produced once per second (other times are also contemplated): top temperature degree F, bottom temperature degree F, top heater duty, bottom heater duty) (in some embodiments, may be available in auto mode);

KP=, KP? (may be used to set or display the KP parameter (e.g., in the 0-255 range)) (in some embodiments, may be available in auto mode);

KI=, KI? (may be used to set or display the Ki parameter (e.g., in the 0-255 range)) (in some embodiments, may be available in auto mode);

KD= , KD? (may be used to set or display the Kd parameter (e.g., in the 0-255 range)) (in some embodiments, may be available in auto mode);

RESET (may be used to reset the device) (in some embodiments, may be available in auto mode);

PID (may be used to display the PID information as well as the temperatures recorded by the temperature probes and the set-point temperature) (in some embodiments, may be available in auto mode);

TCTH= (may be used to set the temperature change threshold in 100ths of a degree Celsius (C)) (in some embodiments, may be available in auto mode);

SNSR= (may be used to input false sensor readings) (in some embodiments, may not be available during auto mode).

Service Temperature Sensors

In some embodiments, this function may read two temperature sensors values (e.g., from TMP175 temperature sensors 2005), convert the read value to degrees C x 100, update the associated digital filters, update the associated global variables, and update a global flag: temperature_in_valid_range. This function may be called from master controller 2301 approximately every 50ms (other time periods are also contemplated). The temperature sensors 2005 may use approximately 220mS to make a 12 bit conversion, so every 5th time the Service Temperature Sensor function is called, it may read both sensors. Other configurations are also contemplated.

tmp175.c and tmp175.h

used for tmp175 specific functions and definitions

temp_sensors.c and temp_sensors.h

used for application specific functions and definitions including the Service_Temperature_Sensors() function.

```
#define TEMP_TOO_LOW_DEGCX100_THRESHOLD 3222 // 32.22°C, 90°F
#define TEMP_TOO_HIGH_DEGCX100_THRESHOLD 4000 // 40°C .0°F
#define TEMP_HYSTERISIS 10 // 1°C
Enum {
    TEMP_SENSOR_ERROR=0,
    TEMP_SENSOR_TOO_LOW,
    TEMP_SENSOR_TOO_HIGH,
    TEMP_SENSOR_OK
    }
    temperature_sensor_state;

    switch (temperature_sensor_state)
    {
        Default:
        Case TEMP_SENSOR_ERROR:
            If either temperature sensor > TEMP_TOO_HIGH + HYSTERESIS
                State = TEMP_SENSOR_TOO_HIGH
            Else
                Temp_too_high = false
        If either temperature sensor < TEMP_TOO_LOW – HYSTERESIS
        {
        State = TEMP_SENSOR_TOO_LOW
        Temp_too_low = true
        }
        Else
            Temp_too_low = false
        If !temp_too_low and !temp_too_high
```

```
        State = TEMP_SENSOR_OK
    Break;

Case TEMP_SENSOR_OK:
    If either temp sensor is < TEMP_TOO_LOW_DEGFX10_THRESHOLD
        State = TEMP_SENSOR_TOO_LOW
    Else If either temp sensor is
    >TEMP_TOO_HIGH_DEGFX10_THRESHOLD
        State = TEMP_SENSOR_TOO_HIGH
    Else
        temperature_too_low = FALSE;
        temperature_too_high = FALSE;
    Break;

Case TEMP_SENSOR_TOO_LOW:
    If both sensors are above minimum temperature + hysteresis
        State = TEMP_SENSOR_OK
    Else
        Temp too low = true
    Break;

Case TEMP_SENSOR_TOO_HIGH:
    If both sensors are below maximum temperature – hysteresis
        State = TEMP_SENSOR_OK
    Else
        Temp too high = true
    Break;
}
Int1 temperature_too_low; // True when either temp sensor is below the low temp
threshold
Int1 temperature_too_high; // True when either temp sensor is above the high
temp threshold
Uint16 top_temp_degc_x100 // temp in deg c x 100 for sensor at top of tub
Uint16 bottom_temp_degc_x100 // temp in deg c x 100 for sensor at bottom of
```

tub

Uint16 avg_temp_degc_x100 // avg of both temp sensors

(e.g. a value of 1234 represents 123.4 deg C)

The digital filter time constant may be around 5 seconds.

[00121] Service Temperature Rate Of Change

This function may calculate a rate of change for the temperature sensors 2005. It may set a flag if the rate of change is too fast. When the rate of change is too fast, this may indicate that the user has changed the temperature by adding bathtub fluid 104 to the bathtub 111.

```
#define RATE_OF_CHANGE_CALC_DELAY (Uint16)(10000/TASK_DELAY_MS) // 10 secs
Uint16 rate_of_change_calc_delay = 0;
Int16 average_temp_change_degc_x100;
// calculate a new rate of change every 10 seconds
rate_of_change_calc_delay++;
If (rate_of_change_calc_delay > RATE_OF_CHANGE_CALC_DELAY)
{
    rate_of_change_calc_delay = 0;
    temperature_change = avg_temp_degf_x10 – old_avg_temp_degf_x10;
    // calculate a rolling average of temperature change so we have a 30 second average window.
    if (average_temp_change > temp_change_threshold_degc_x100)
    rate_of_change_too_fast = TRUE;
    else
    rate_of_change_too_fast = FALSE;
    }
```

[00122] Service Heater

This function may control the heater (e.g., wire heating elements) with phase angle firing. In some embodiments, the duty cycle may be 0-1000. In some embodiments, the heater duty cycle may be varied using a PID control algorithm that closes the loop around the measured water temperature and the water setpoint temperature.

In some embodiments, the PID algorithm may be executed and a new duty cycle may be produced at the end of each period (e.g., approximately 2.1 seconds) (other periods are also contemplated).

Heater.c and heater.h may be used for application specific functions and definitions including the Service_Heater() function.

[00123] In some embodiments, the heater may be turned off at every zero crossing. In some embodiments, immediately after synching to the zero crossing timer 0 may be reloaded with (65535 – calculated value) so that when timer 0 overflows the TRIAC may be turned on for the requested duty cycle. In some embodiments, a 25% duty cycle may mean that the TRIAC will be turned on 25% of the time, (however, it may not equate to 25% of the power available in the AC sine wave). In some embodiments, both heaters may use the same duty cycle and may turn on at approximately the same time. They may be controlled together or independently.

[00124] FIG. 24 illustrates a flowchart for temperature managed bathtub heating system control, according to an embodiment. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[00125] At 2401, temperature at one or more temperature sensors 2005 may be detected.

[00126] At 2403, an LED (or other indicator) indicating the bathtub heating system 100 is on may not be illuminated until a temperature of the bathtub fluid 104 is detected to be above a threshold.

[00127] At 2405, the bathtub heating system 100 may monitor the temperature of the bathtub fluid 104 from one or more of the temperature sensors 2005 until the temperature is above the threshold (as long as the temperature is below the threshold, the bathtub heating system 100 may keep the LED (or other indicator) off)

[00128] At 2407, an LED may be illuminated to indicate the bathtub heating system 100 has detected a temperature change indicative of bathtub fluid 104 being added to the bathtub 111.

[00129] At 2409, the bathtub heating system 100 may wait a time period (e.g., 30 seconds). Other time periods are also contemplated.

[00130] At 2411, a determination may be made as to whether the temperature of the bathtub fluid 104 has changed by at least a specified amount (e.g., 3 %, 10 degrees F, etc). If the temperature has not changed by the specified amount, the flow may return to 2407.

[00131] At 2413, if the temperature has changed by at least the specified amount, an LED (or other indicator) may be illuminated to show the bathtub heating system 100 is actively heating the bathtub fluid 104.

[00132] At 2415, a determination may be made whether the temperature of the bathtub fluid 104 is above an upper threshold (e.g., a default temperature threshold, a user specified maximum temperature threshold, etc). In some embodiments, the upper threshold may be approximately 130 degrees F (other temperatures are also contemplated).

[00133] At 2417, if the temperature is not above the upper threshold, a determination may be made as to whether the temperature is below a lower threshold (e.g., a default temperature threshold, a user specified minimum temperature threshold, etc).

[00134] At 2419, if the temperature is not below the lower threshold, the bathtub heating system 100 may determine if the rate of temperature change is too fast (e.g., if the temperature is changing at a rate greater than a rate threshold). The rate threshold may be a default value or a user specified rate threshold (e.g., +2 to -2 degrees F in a time range of 1-2 seconds). If the temperature is changing greater than the rate threshold, flow may return to 2407 to stop or decrease applied heat until the temperature stabilizes. A temperature change greater than the rate threshold may indicate the user is adding/draining bathtub fluid 104 to adjust the temperature.

[00135] At 2421, if the temperature is not changing greater than the rate threshold, the bathtub heating system 100 may determine if there is a loss of bathtub fluid 104 (e.g., if the fluid level in the bathtub 111 has fallen below the level of a fluid level detection sensor). If fluid loss is not detected, flow may return to 2413 to continue applying heat to the bathtub fluid 104.

[00136] At 2423, if fluid loss is detected, the bathtub heating system 100 may stop or reduce heat applied and may indicate (e.g., through an LED) that heat has been stopped or reduced. In some embodiments, the bathtub heating system 100 may indicate that the fluid level is below a certain level.

[00137] At 2425, the bathtub heating system 100 may monitor a temperature of the bathtub fluid 104, and if the rate of temperature change of the bathtub fluid 104 is above a specified rate (e.g., approximately +5 to -5 degrees F in a time range of approximately 1-2 seconds, or, for example, greater than approximately 5% in approximately 1-2 seconds), the flow may return to 2417 to determine if the temperature of the bathtub fluid 104 is below a lower threshold.

[00138] At 2427, (from 2415) if the temperature is above the upper threshold, the bathtub heating system 100 may stop applying heat or may apply less heat to the bathtub fluid 104. In some embodiments, the bathtub heating system 100 may indicate (e.g., through an LED) that the bathtub heating system 100 has stopped or decreased heating.

[00139] At 2429, another determination may be made as to whether the temperature of the bathtub fluid 104 is above the upper threshold. If the temperature is above the upper threshold, flow may return to 2427 to continue not applying heat (or reducing the amount of heat applied).

[00140] At 2431, (from 2417) if the temperature is below the lower threshold (e.g., approximately 90 degrees F) or (from 2429) if the temperature is not above the upper threshold, the bathtub heating system 100 may stop applying heat or may apply less heat to the bathtub fluid 104. In some embodiments, the bathtub heating system 100 may indicate (e.g., through an LED) that the bathtub heating system 100 has stopped or decreased heating. In some embodiments, the temperature may have fallen below the lower threshold if the bathtub fluid 104 was drained below the level of one of the temperature sensors 2005 (such that the temperature sensor (e.g., temperature sensor 2005a) is detecting the temperature of the air). The heating applied may be decreased or stop to avoid excessive heat buildup on the bathtub surface.

[00141] At 2433, a time period may elapse (e.g., approximately 5 minutes). After the time period (which may be a default value, user specified value, etc.) elapses, flow may return to 2403. Until the time period elapses, flow may continue at 2431.

[00142] FIG. 25 illustrates a method for manufacturing a bathtub, according to an embodiment. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[00143] At 2501, a bathtub may be provided that is configured to hold a bathtub fluid. The bathtub may include bottom and side walls (each with an interior and exterior surface).

[00144] At 2503, a heating element may be coupled to the bathtub. The heating element may be positioned 1) proximate to the exterior surface of at least one of the bottom and/or side walls and/or 2) within at least one of the bottom and/or side walls. The heating element may be integrated into the walls or attached through a clip, adhesive, etc.

[00145] At 2505, a fluid level sensor may be coupled to the bathtub to detect a presence of a fluid within the bathtub. The heating element may be configured to heat the bottom and/or side walls of the bathtub to heat the bathtub fluid within the bathtub when the fluid level sensor detects a presence of a fluid within the bathtub.

[00146] Embodiments of a subset or all (and portions or all) of the above may be implemented by program instructions stored in a memory medium or carrier medium and executed by a processor (e.g., processors 1401). A memory medium may include any of various types of memory devices or storage devices. The term "memory medium" is intended to include an installation medium, e.g., a Compact Disc Read Only Memory (CD-ROM), floppy disks, or tape device; a computer system memory or random access memory such as Dynamic Random Access Memory (DRAM), Double Data Rate Random Access Memory (DDR RAM), Static Random Access Memory (SRAM), Extended Data Out Random Access Memory (EDO RAM), Rambus Random Access Memory (RAM), etc.; or a non-volatile memory such as a magnetic media, e.g., a hard drive, or optical storage. The memory medium may comprise other types of memory as well, or combinations thereof. In addition, the memory medium may be located in a first computer in which the programs are executed, or may be located in a second different computer that connects to the first computer over a network, such as the Internet. In the latter instance, the second computer may provide program instructions to the first computer for execution. The term "memory medium" may include two or more memory mediums that may reside in different locations, e.g., in different computers that are connected over a network.

[00147] In some embodiments, a computer system at a respective participant location may include a memory medium(s) on which one or more computer programs or software components according to one embodiment of the present invention may be stored. For example, the memory medium may store one or more programs that are executable to perform the methods described herein. The memory medium may also store operating system software, as well as other software for operation of the computer system.

[00148] Further modifications and alternative embodiments of various aspects of the invention may be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is to be understood that the forms of the invention shown and described herein are to be taken as embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims.

WHAT IS CLAIMED IS:

1. A bathtub comprising a bathtub heating system, comprising:

a bathtub configured to hold a bathtub fluid, wherein the bathtub comprises a bottom and side walls, wherein each of the bottom and side walls include an interior and exterior surface;

a heating element that is positioned 1) proximate to the exterior surface of at least one of the bottom and/or side walls; and/or 2) within at least one of the bottom and/or side walls; and

a sensor operable to detect a presence of a fluid within the bathtub;

wherein the heating element is configured to heat the bottom and/or side walls of the bathtub to thereby heat the bathtub fluid within the bathtub when the sensor detects a presence of a fluid within the bathtub.

2. The bathtub of claim 1, further comprising:

a temperature sensor;

wherein a temperature detected by the temperature sensor is associated with a temperature of the bathtub fluid in the bathtub and wherein the detected temperature is used to approximately maintain the temperature of the bathtub fluid.

3. The bathtub of claim 1,

wherein the bathtub heating system is operable to maintain a temperature of the bathtub fluid after an initial temperature adjustment period; and

wherein the initial temperature adjustment period is a period during which a user adds bathtub fluid to the bathtub of a different temperature than the bathtub fluid in the bathtub.

4. The bathtub of claim 3, further comprising maintaining a second bathtub fluid temperature detected during a subsequent temperature adjustment period that is subsequent to the initial temperature adjustment period.

5. The bathtub of claim 4, wherein the subsequent temperature adjustment period is determined by the bathtub heating system monitoring detected temperatures from a temperature sensor and wherein the subsequent temperature adjustment period is defined as a period during which a detected temperature change rate of the bathtub fluid exceeds a threshold.

6. The bathtub of claim 1, wherein the heating element is nichrome ribbon.

7. The bathtub of claim 1, further comprising:

a faucet; and

a drain;

wherein the bathtub is configured to receive the bathtub fluid from the faucet and wherein the drain is configured to allow the bathtub fluid to exit the bathtub.

8. The bathtub of claim 1, wherein power is applied to the heating element to approximately maintain a temperature of the bathtub fluid in the bathtub.

9. The bathtub of claim 1, wherein power is applied to the heating element, and wherein the power applied to the heating element is applied to achieve a variable bathtub fluid temperature.

10. A bathtub heating system for a bathtub, wherein the bathtub is configured to hold a bathtub fluid, wherein the bathtub comprises a bottom and side walls, wherein each of the bottom and side walls include an interior and exterior surface, the bathtub heating system comprising:

a heating element that is adapted to be positioned 1) proximate to the exterior surface of at least one of the bottom and/or side walls; and/or 2) within at least one of the bottom and/or side walls; and

a sensor operable to detect a presence of a fluid within the bathtub;

wherein the heating element is configured to heat the bathtub fluid within the bathtub when the sensor detects a presence of a fluid within the bathtub.

11. The bathtub heating system of claim 10, further comprising:

a temperature sensor;

wherein a temperature detected by the temperature sensor is associated with a temperature of the bathtub fluid in the bathtub and wherein the detected temperature is used to approximately maintain the temperature of the bathtub fluid.

12. The bathtub heating system of claim 10,

wherein the bathtub heating system is operable to maintain a temperature of the bathtub fluid after an initial temperature adjustment period; and wherein the initial temperature adjustment period is a period during which a user adds bathtub fluid to the bathtub of a different temperature than the bathtub fluid in the bathtub.

13. The bathtub heating system of claim 12, further comprising maintaining a second bathtub fluid temperature detected during a subsequent temperature adjustment period that is subsequent to the initial temperature adjustment period.

14. The bathtub heating system of claim 13, wherein the subsequent temperature adjustment period is determined by the bathtub heating system monitoring detected temperatures from a temperature sensor and wherein the subsequent temperature adjustment period is defined as a period during which a detected temperature change rate of the bathtub fluid exceeds a threshold.

15. The bathtub heating system of claim 10, wherein the heating element is nichrome ribbon.

16. The bathtub heating system of claim 10, further comprising:

a faucet; and

a drain;

wherein the bathtub is configured to receive the bathtub fluid from the faucet and wherein the drain is configured to allow the bathtub fluid to exit the bathtub.

17. The bathtub heating system of claim 10, wherein power is applied to the heating element to approximately maintain a temperature of the bathtub fluid in the bathtub.

18. The bathtub heating system of claim 10, wherein power is applied to the heating element, and wherein the power applied to the heating element is applied to achieve a variable bathtub fluid temperature.

19. A method of manufacturing a bathtub, comprising:

providing a bathtub configured to hold a bathtub fluid, wherein the bathtub comprises a bottom and side walls, wherein each of the bottom and side walls include an interior and exterior surface;

coupling a heating element to the bathtub, wherein the heating element is positioned 1) proximate to the exterior surface of at least one of the bottom and/or side walls; and/or 2) within at least one of the bottom and/or side walls; and coupling a sensor to the bathtub, wherein the sensor is operable to detect a presence of a fluid within the bathtub;

wherein the heating element is configured to heat the bottom and/or side walls of the bathtub to thereby heat the bathtub fluid within the bathtub when the sensor detects a presence of a fluid within the bathtub.

20. The method of claim 19, further comprising:

coupling a temperature sensor to the bathtub;

wherein a temperature detected by the temperature sensor is associated with a temperature of the bathtub fluid in the bathtub and wherein the detected temperature is used to approximately maintain the temperature of the bathtub fluid.

21. A method of operating a bathtub, wherein the bathtub is configured to hold a bathtub fluid, wherein the bathtub comprises a bottom and side walls, wherein each of the bottom and side walls include an interior and exterior surface, the bathtub heating system comprising, comprising:

detecting a presence of a fluid in the bathtub, wherein the presence of the fluid is detected through a sensor; and

applying heat to the bathtub fluid in the bathtub through a heating element, wherein the heating element is positioned 1) proximate to the exterior surface of at least one of the bottom and/or side walls; and/or 2) within at least one of the bottom and/or side walls;

wherein the heating element is configured to heat the bottom and/or side walls of the bathtub to thereby heat the bathtub fluid within the bathtub when the sensor detects a presence of a fluid within the bathtub.

22. The method of claim 21, further comprising:

detecting a temperature of the bathtub fluid through a temperature sensor;

wherein the temperature detected by the temperature sensor is associated with a temperature of the bathtub fluid in the bathtub and wherein the detected temperature is used to approximately maintain the temperature of the bathtub fluid.

23. A bathtub comprising a bathtub heating system, comprising:

a tub means configured to hold a bathtub fluid, wherein the tub means comprises a bottom and side walls, wherein each of the bottom and side walls include an interior and exterior surface;

a heating means that is positioned 1) proximate to the exterior surface of at least one of the bottom and/or side walls; and/or 2) within at least one of the bottom and/or side walls; and

a sensor means operable to detect a presence of a bathtub fluid within the tub means;

wherein the heating means is configured to heat the bottom and/or side walls of the tub means to thereby heat the bathtub fluid within the tub means when the sensor detects a presence of a bathtub fluid within the tub means.

24. The bathtub of claim 23, further comprising:

a temperature sensor means;

wherein a temperature detected by the temperature sensor means is associated with a temperature of the bathtub fluid in the tub means and wherein the detected temperature is used to approximately maintain the temperature of the bathtub fluid.

25. The bathtub of claim 23, wherein the bathtub heating system is configured to heat the bathtub fluid in the tub means without circulating the bathtub fluid in the tub means.

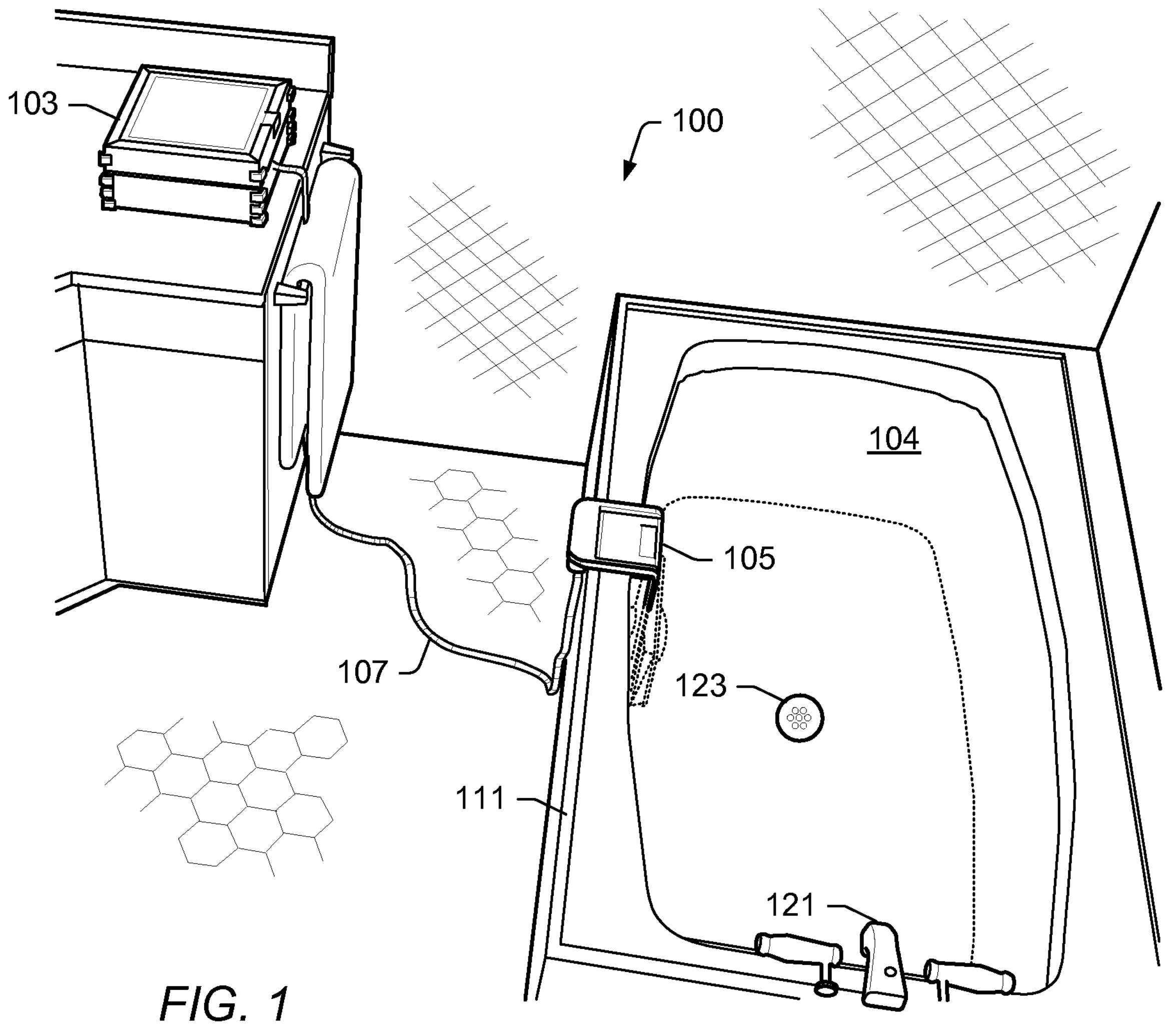

103
100
104
105
107
123
111
121

FIG. 1

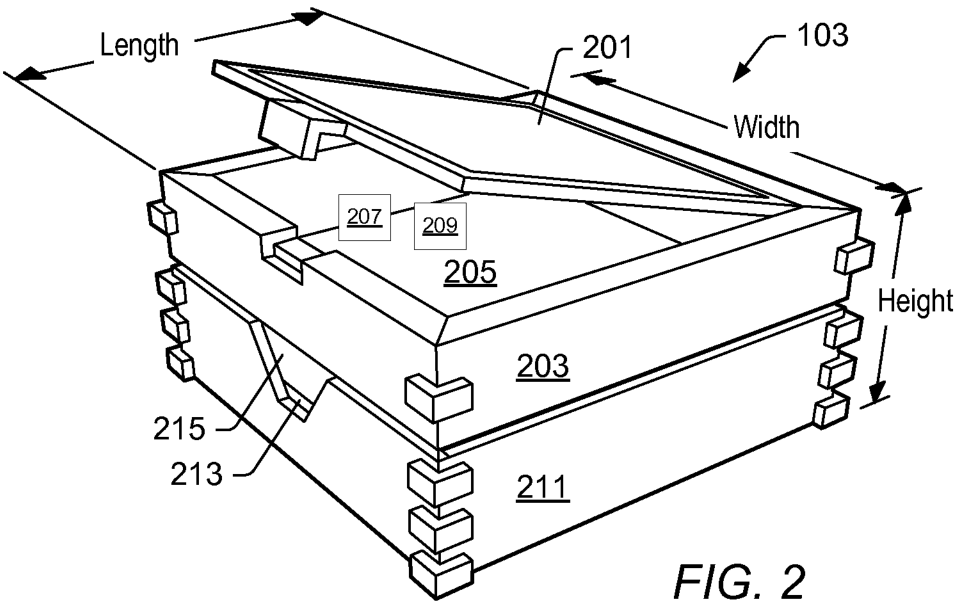

Length
201
103
Width
207
209
205
Height
203
215
213
211

FIG. 2

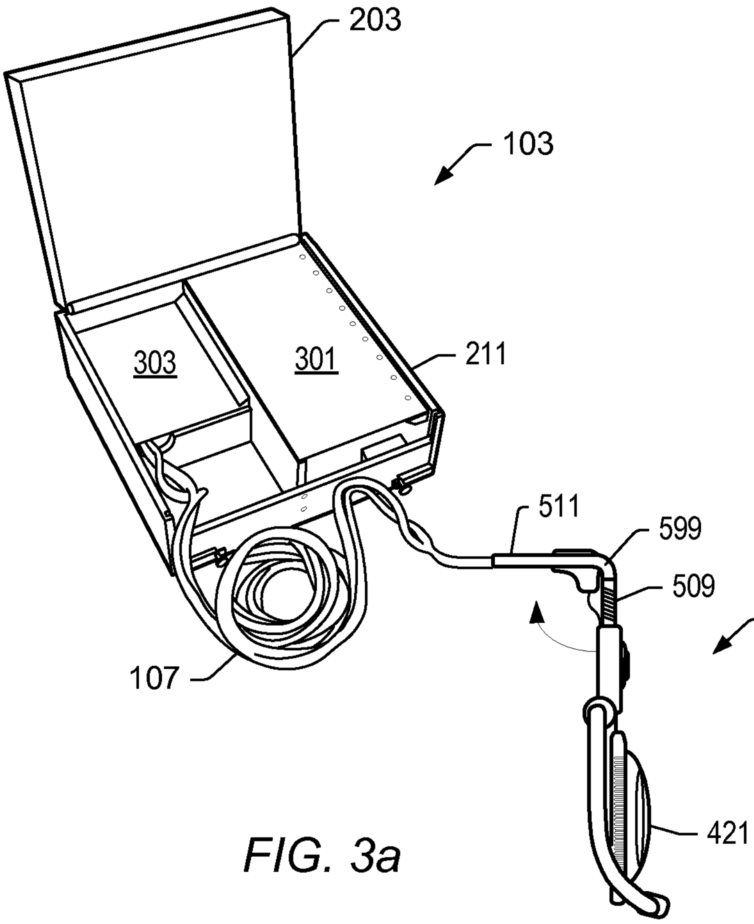

203
103
303
301
211
511
599
509
501
107
421

FIG. 3a

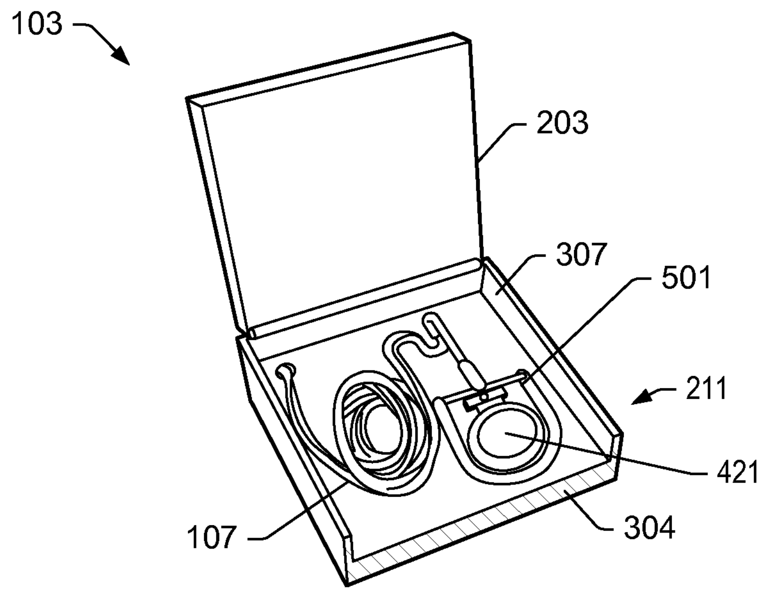

103
203
307
501
211
421
107
304

FIG. 3b

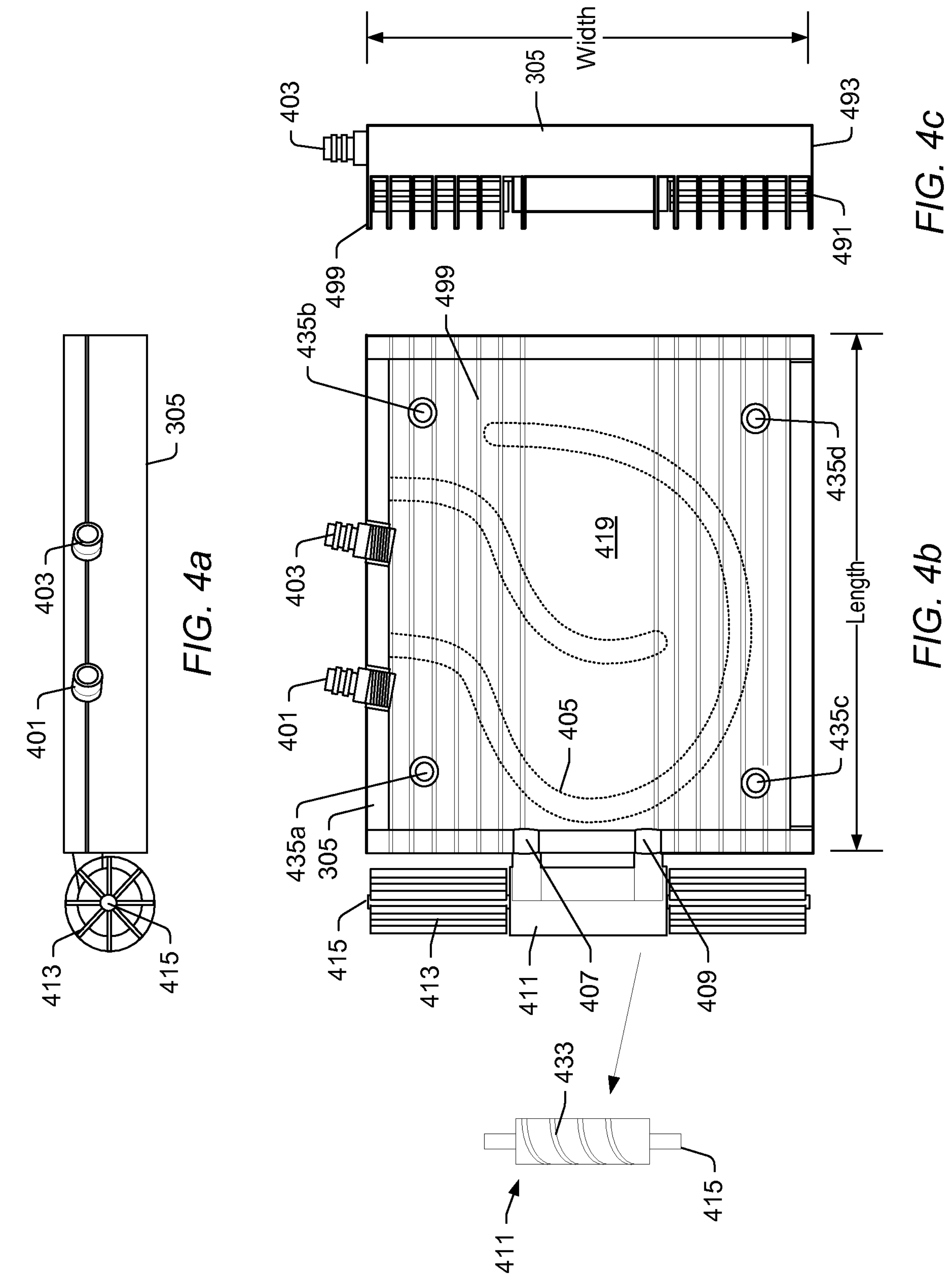


FIG. 4a

FIG. 4b

FIG. 4c

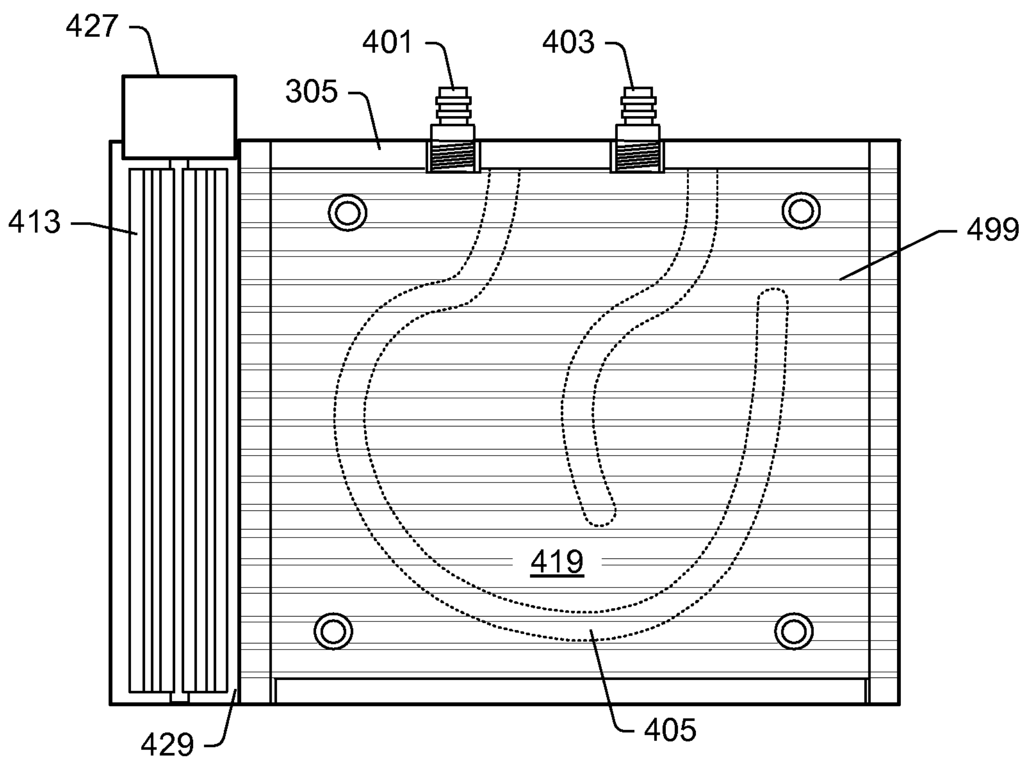


FIG. 4d

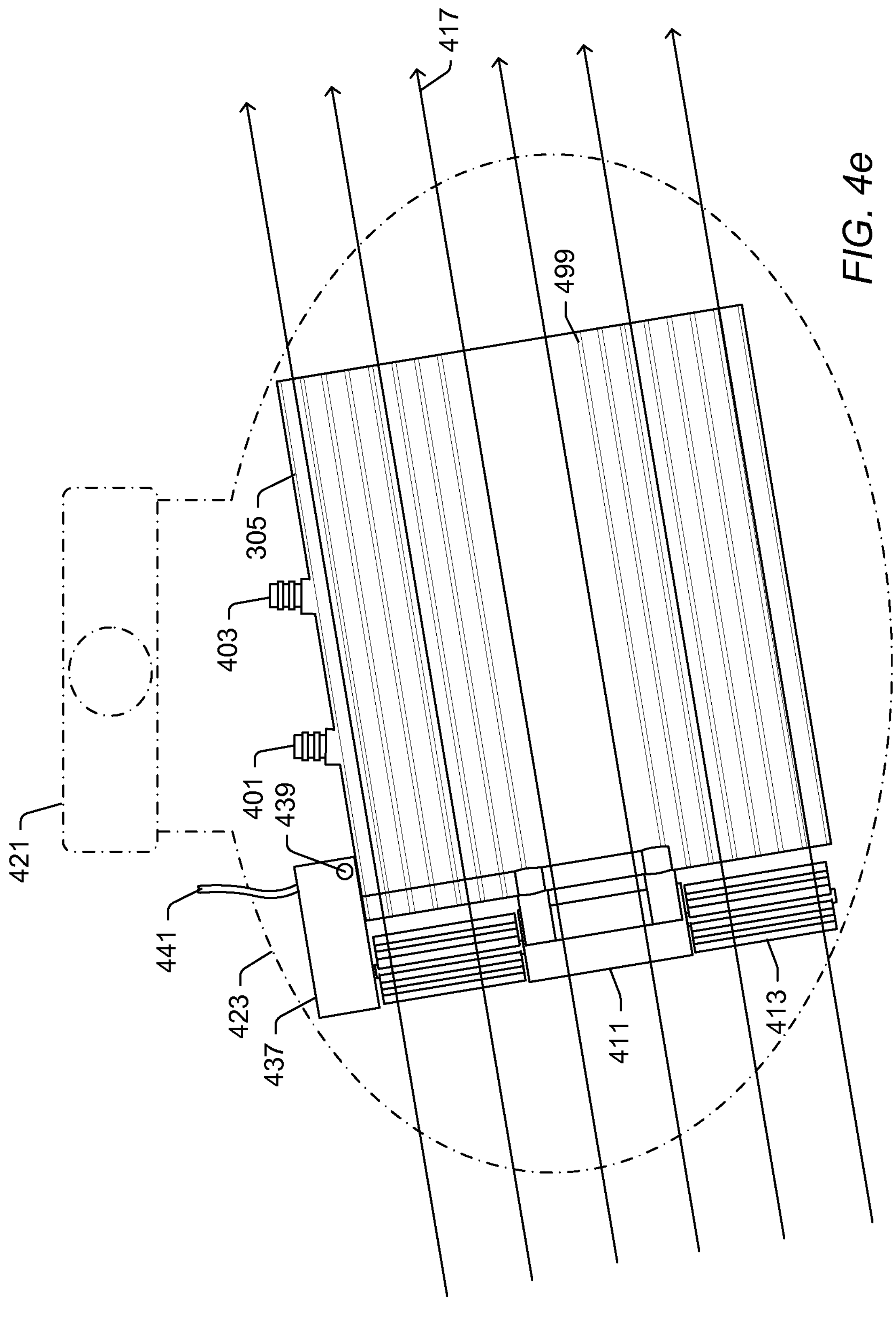


FIG. 4e

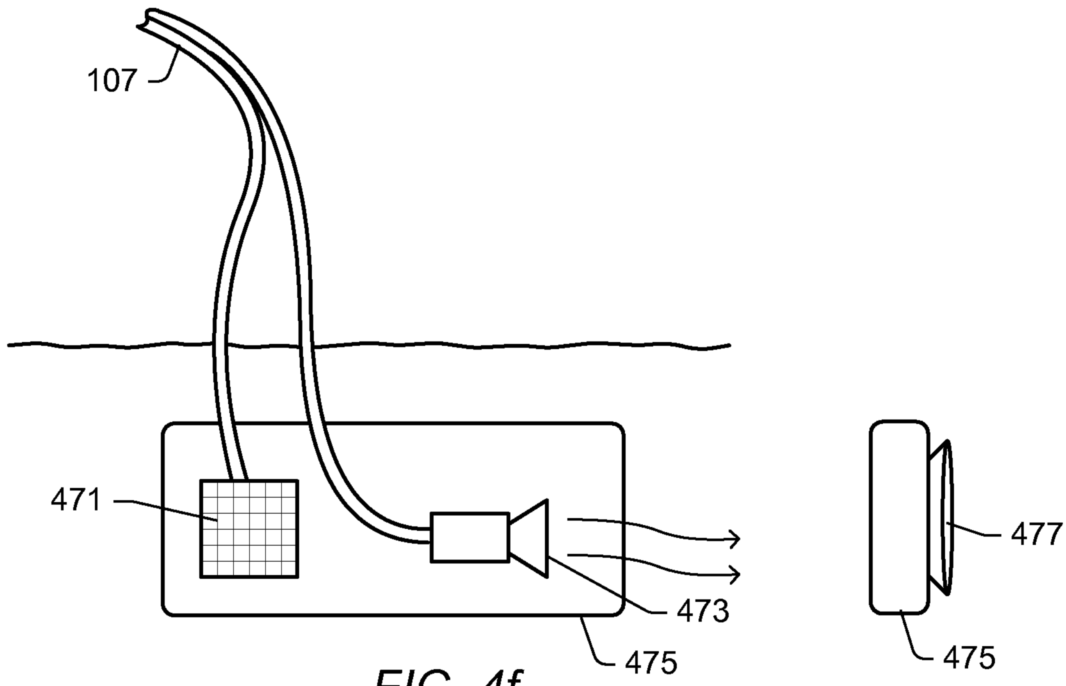


FIG. 4f

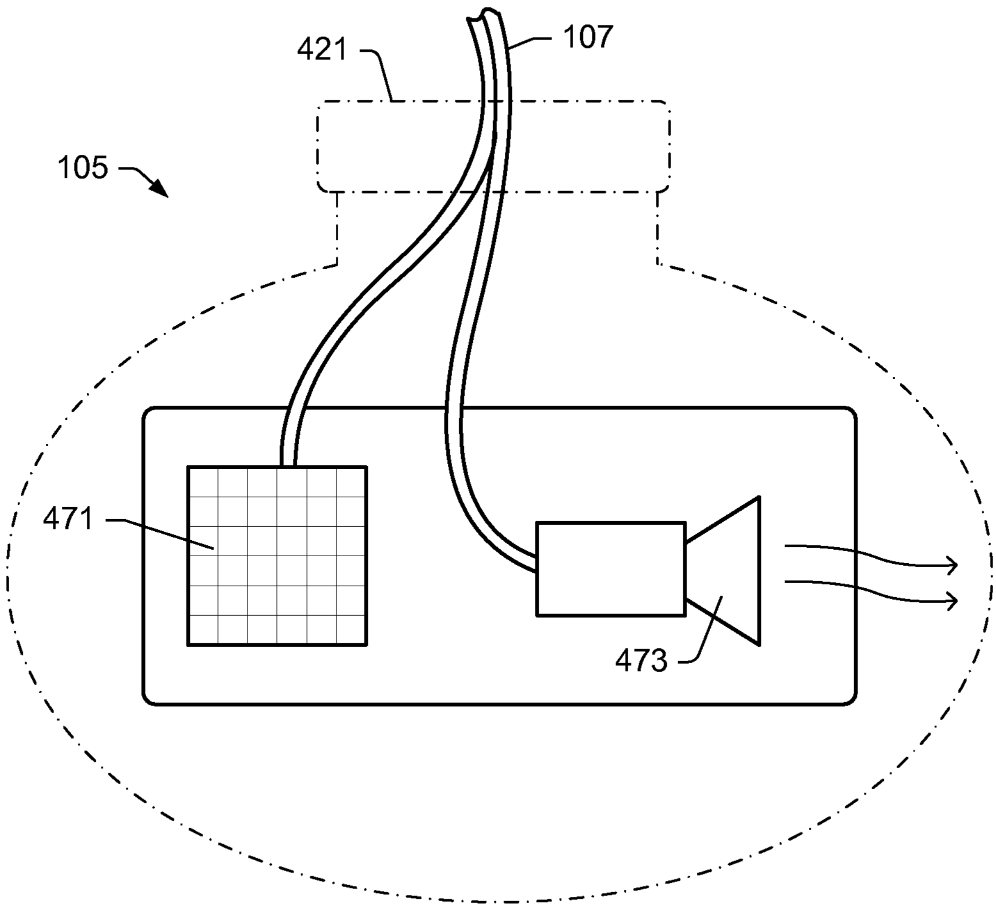


FIG. 4g

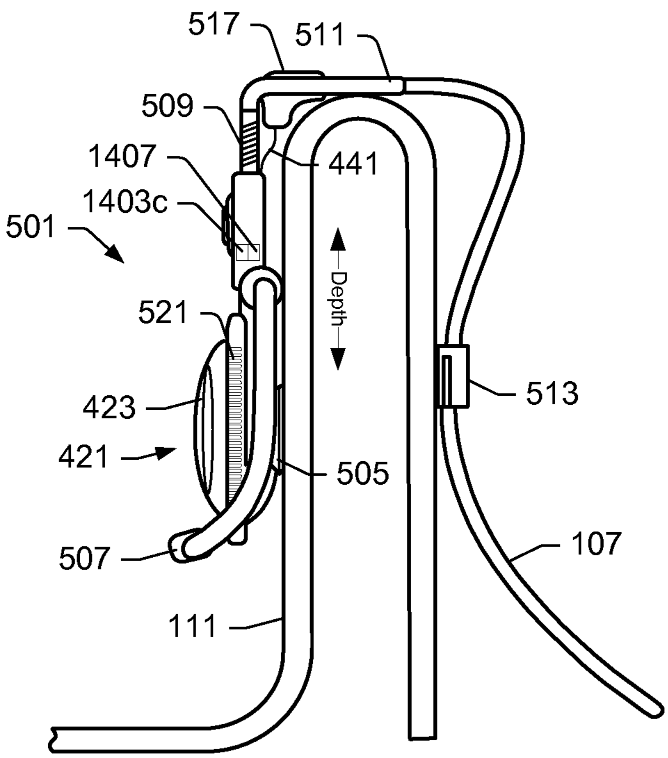


FIG. 5

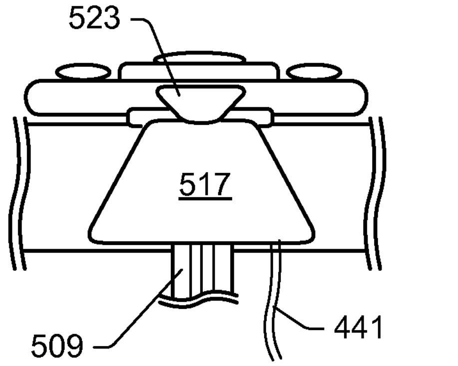


FIG. 6

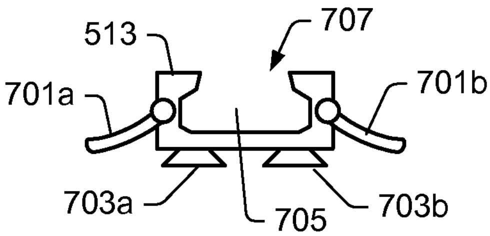


FIG. 7

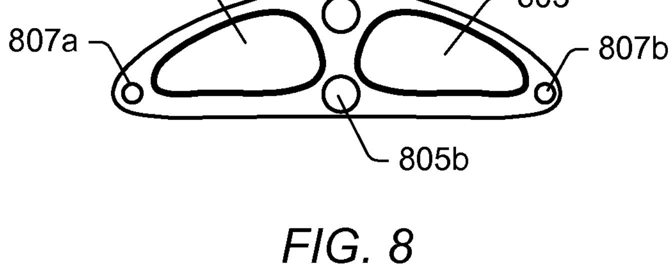


FIG. 8

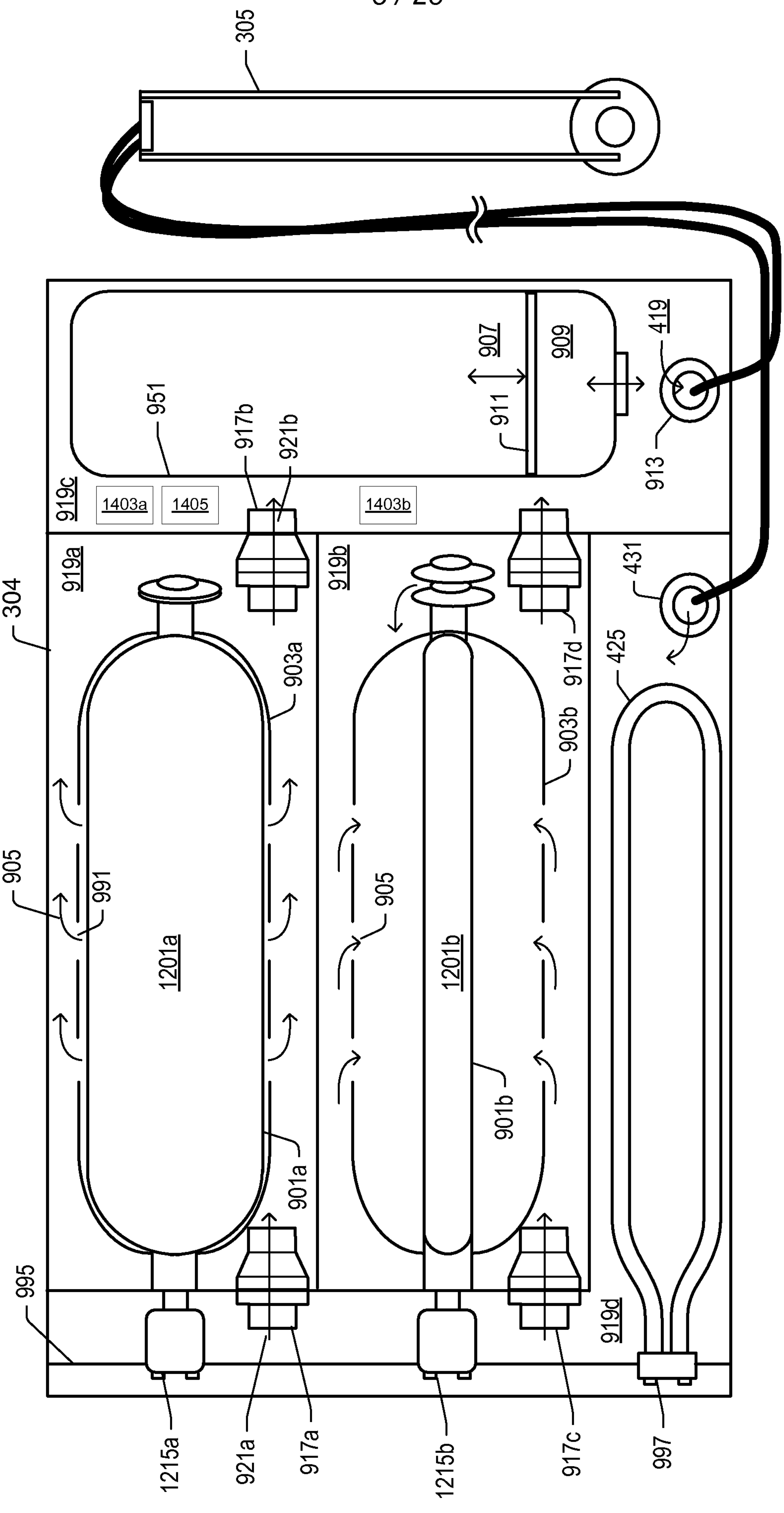

305
419
907
909
951
917b
921b
911
913
919c
1403a
1405
1403b
919a
919b
304
431
425
903a
917d
903b
905
991
905
1201a
1201b
901b
901a
995
919d
1215a
921a
917a
1215b
917c
997

FIG. 9

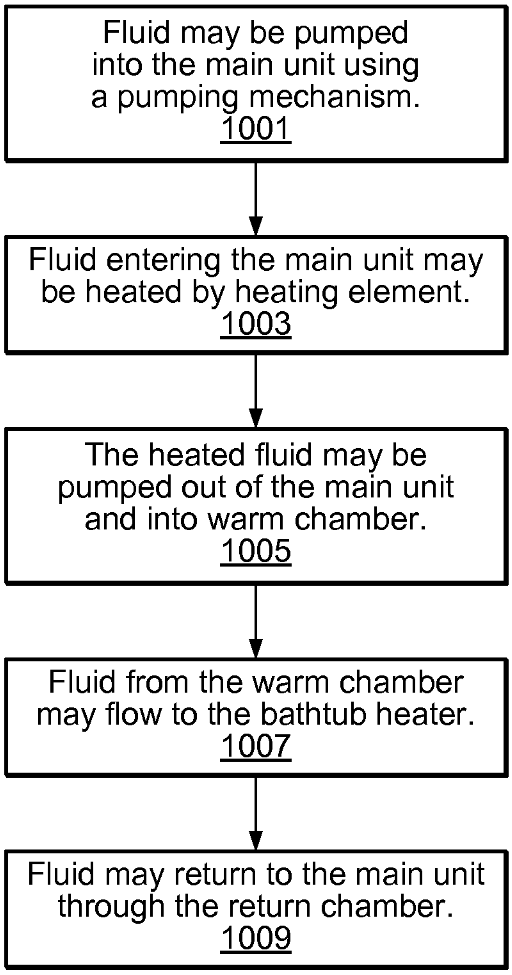

Fluid may be pumped into the main unit using a pumping mechanism.
1001
Fluid entering the main unit may be heated by heating element.
1003
The heated fluid may be pumped out of the main unit and into warm chamber.
1005
Fluid from the warm chamber may flow to the bathtub heater.
1007
Fluid may return to the main unit through the return chamber.
1009

FIG. 10

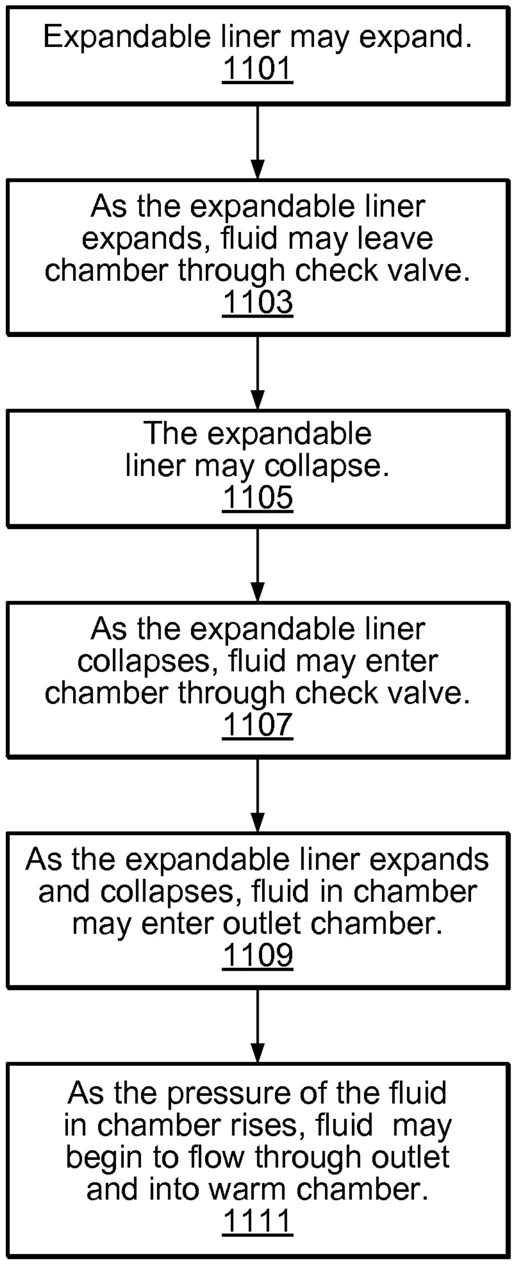

Expandable liner may expand.
1101
As the expandable liner expands, fluid may leave chamber through check valve.
1103
The expandable liner may collapse.
1105
As the expandable liner collapses, fluid may enter chamber through check valve.
1107
As the expandable liner expands and collapses, fluid in chamber may enter outlet chamber.
1109
As the pressure of the fluid in chamber rises, fluid may begin to flow through outlet and into warm chamber.
1111

FIG. 11

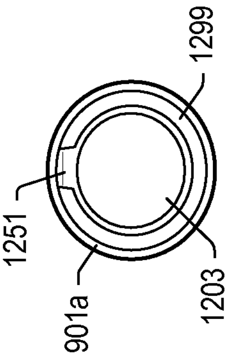


FIG. 12b

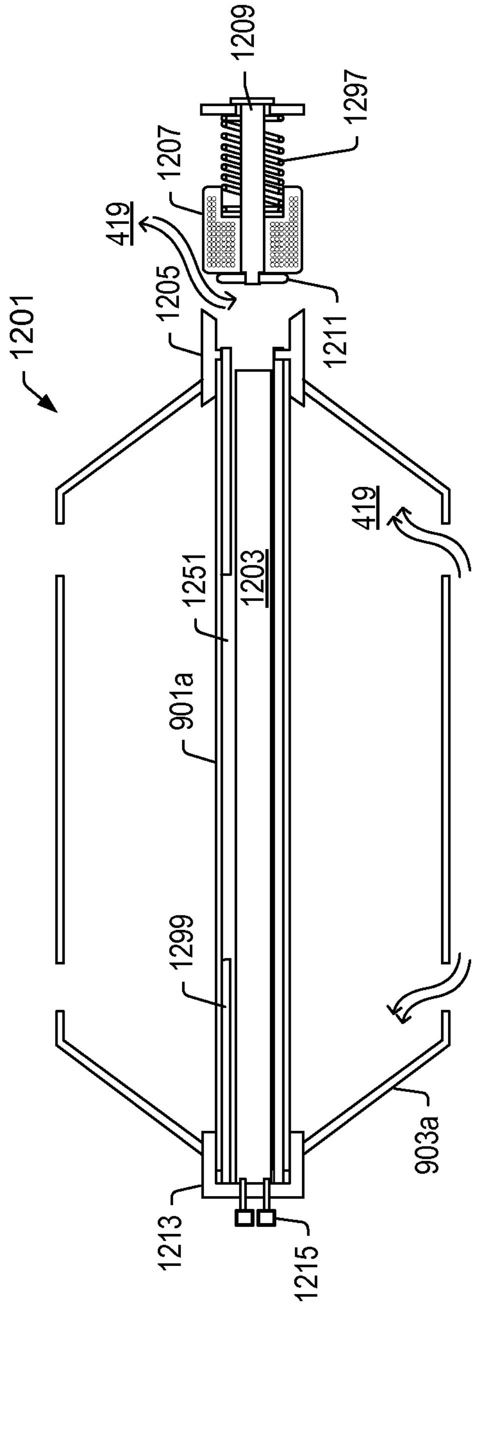


FIG. 12a

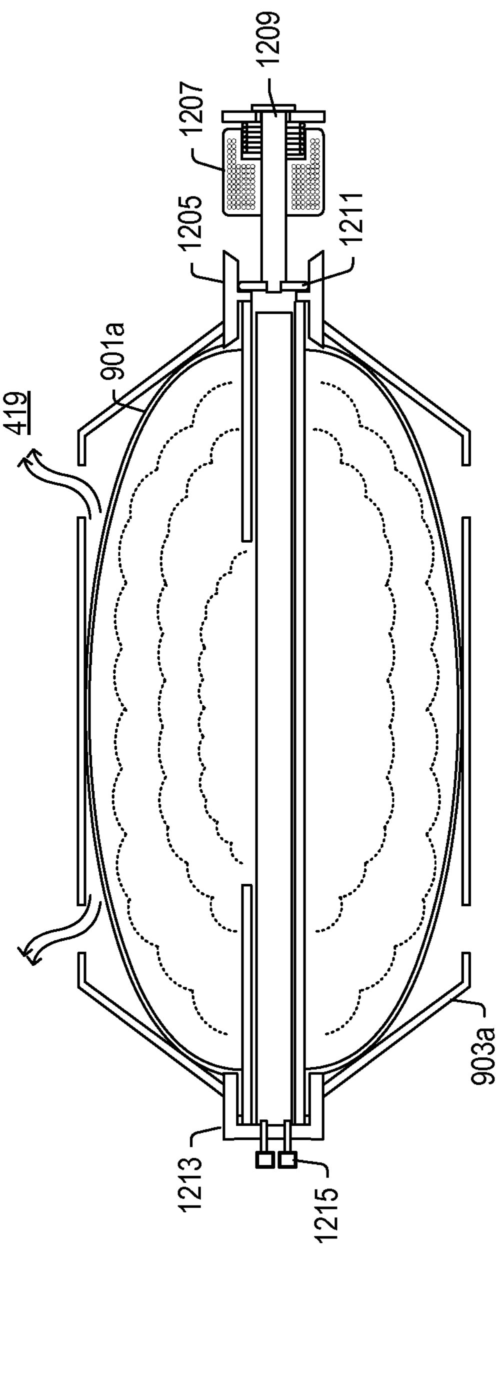


FIG. 12c

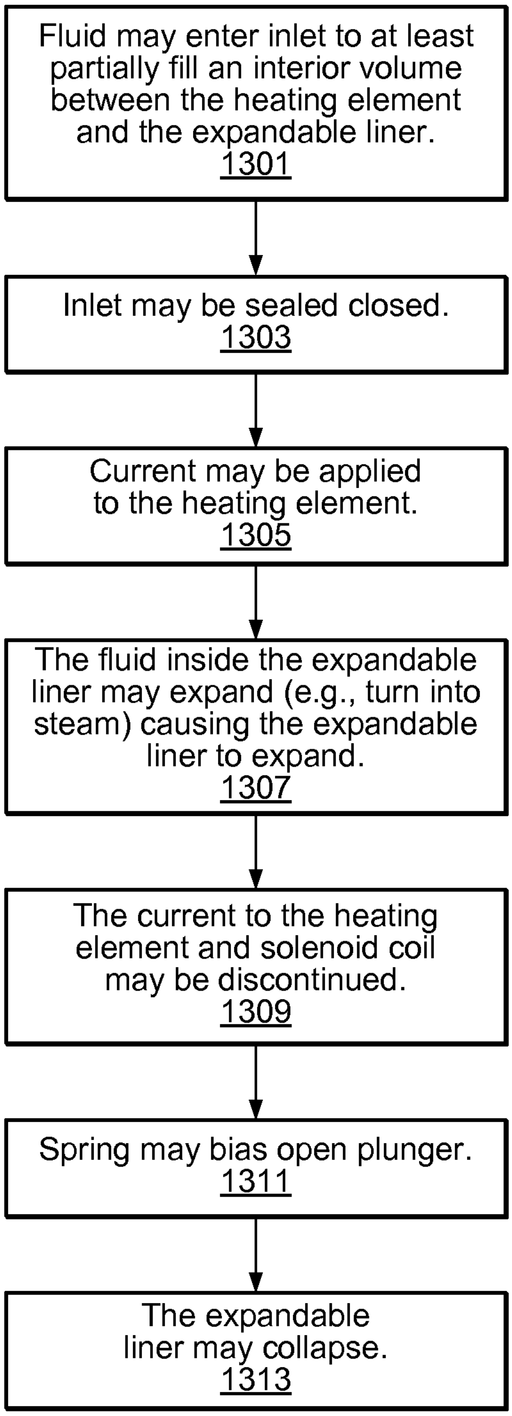

Fluid may enter inlet to at least partially fill an interior volume between the heating element and the expandable liner.
1301
Inlet may be sealed closed.
1303
Current may be applied to the heating element.
1305
The fluid inside the expandable liner may expand (e.g., turn into steam) causing the expandable liner to expand.
1307
The current to the heating element and solenoid coil may be discontinued.
1309
Spring may bias open plunger.
1311
The expandable liner may collapse.
1313

FIG. 13

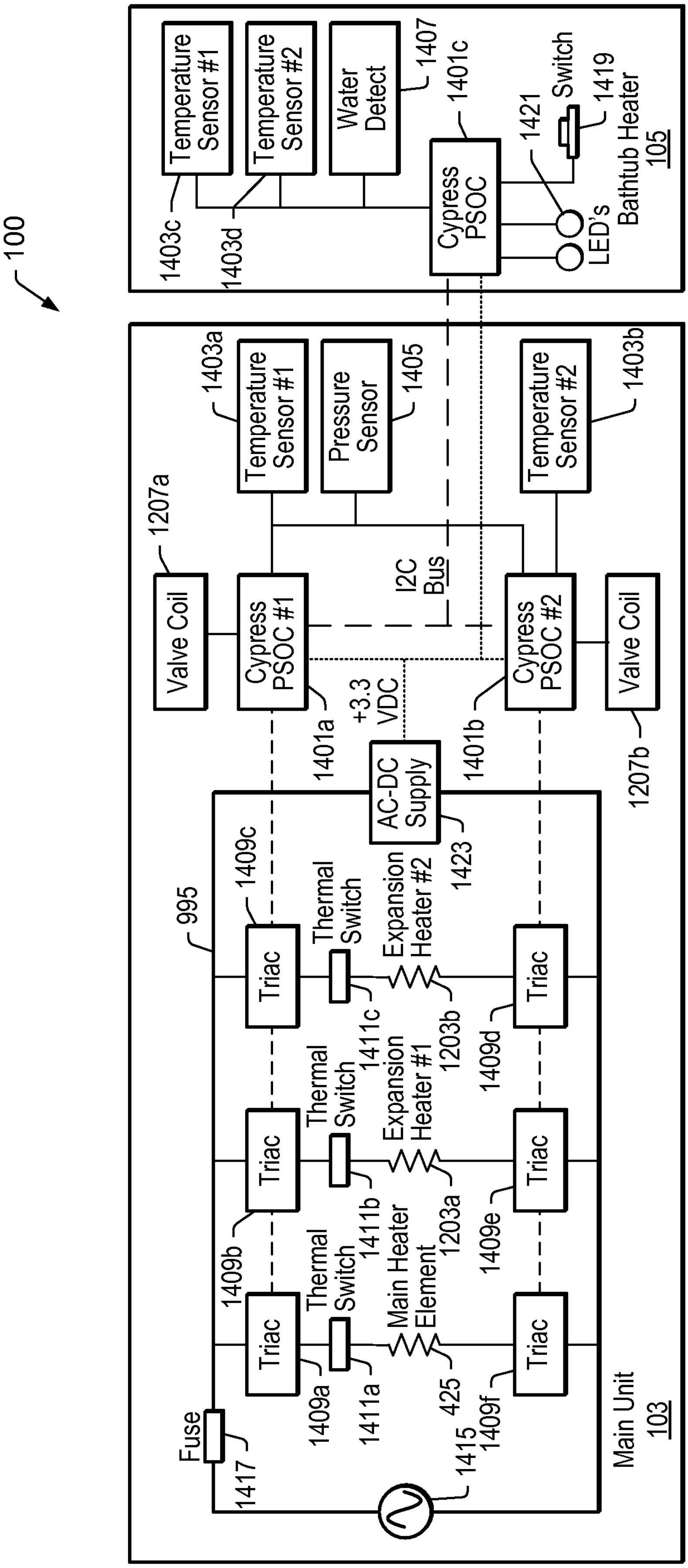

100
Temperature Sensor #1
Temperature Sensor #2
Water Detect
1407
1401c
Cypress PSOC
1421
Switch
1419
LED's
Bathtub Heater
105
1403c
1403d
1403a
Temperature Sensor #1
Pressure Sensor
1405
Temperature Sensor #2
1403b
1207a
Valve Coil
Cypress PSOC #1
I2C Bus
Cypress PSOC #2
Valve Coil
1401a
+3.3 VDC
1401b
1207b
AC-DC Supply
1423
995
1409c
Triac
Thermal Switch
Expansion Heater #2
Triac
1411c
1203b
1409d
Triac
Thermal Switch
Expansion Heater #1
Triac
1409b
1411b
1203a
1409e
Triac
Thermal Switch
Main Heater Element
Triac
1409a
1411a
425
1409f
Fuse
1417
1415
Main Unit
103

FIG. 14

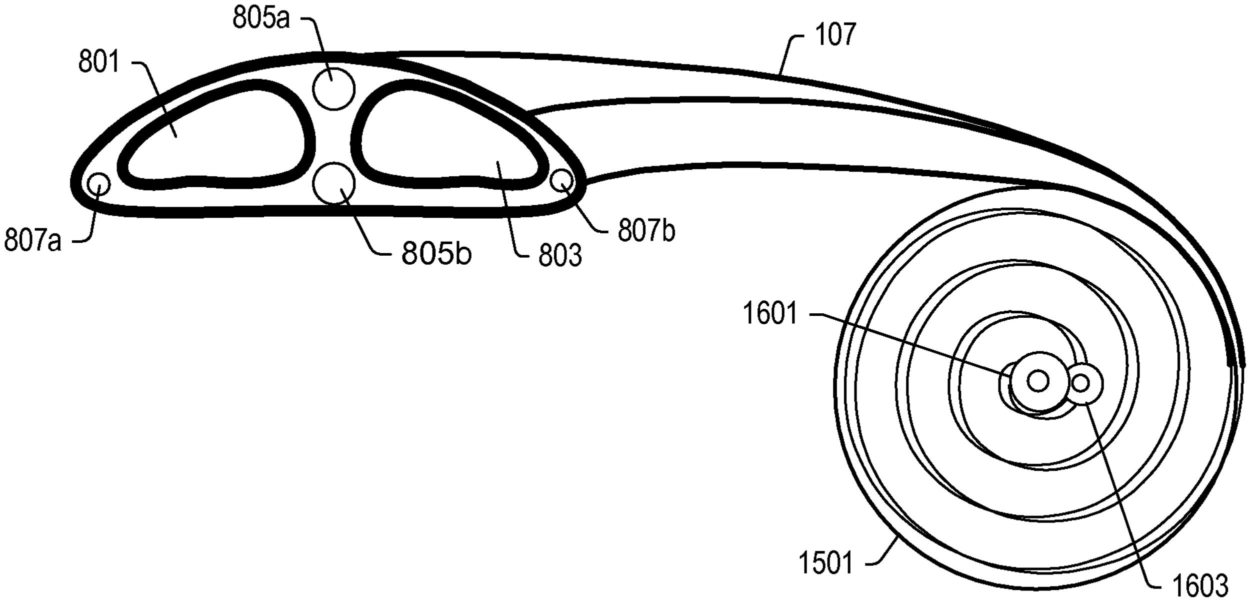


FIG. 15

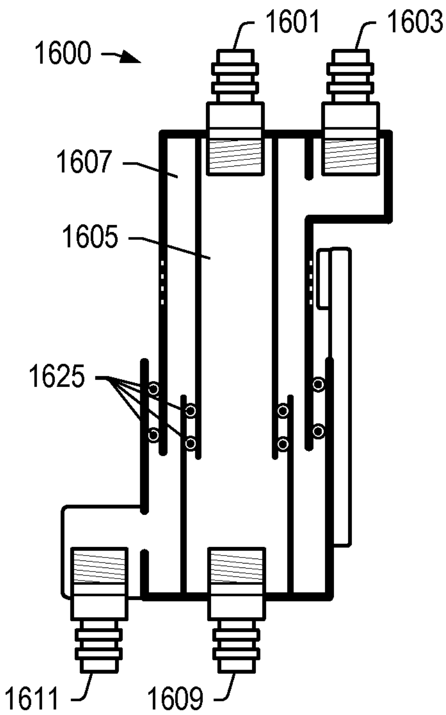


FIG. 16a

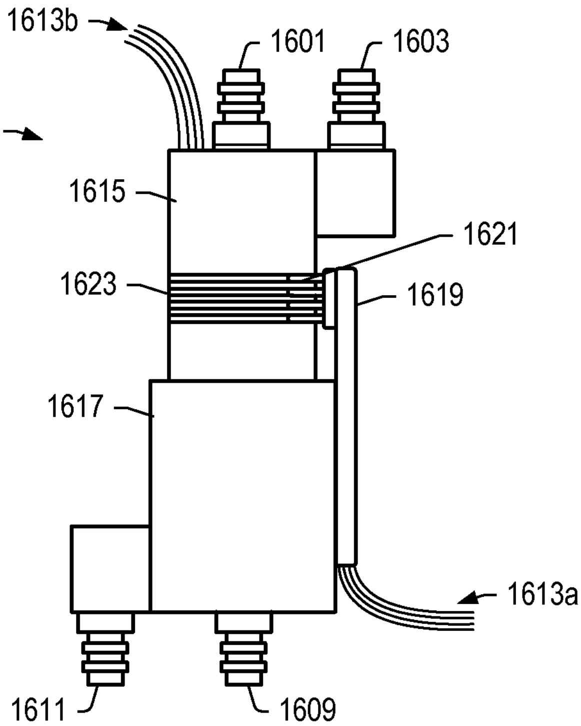


FIG. 16b

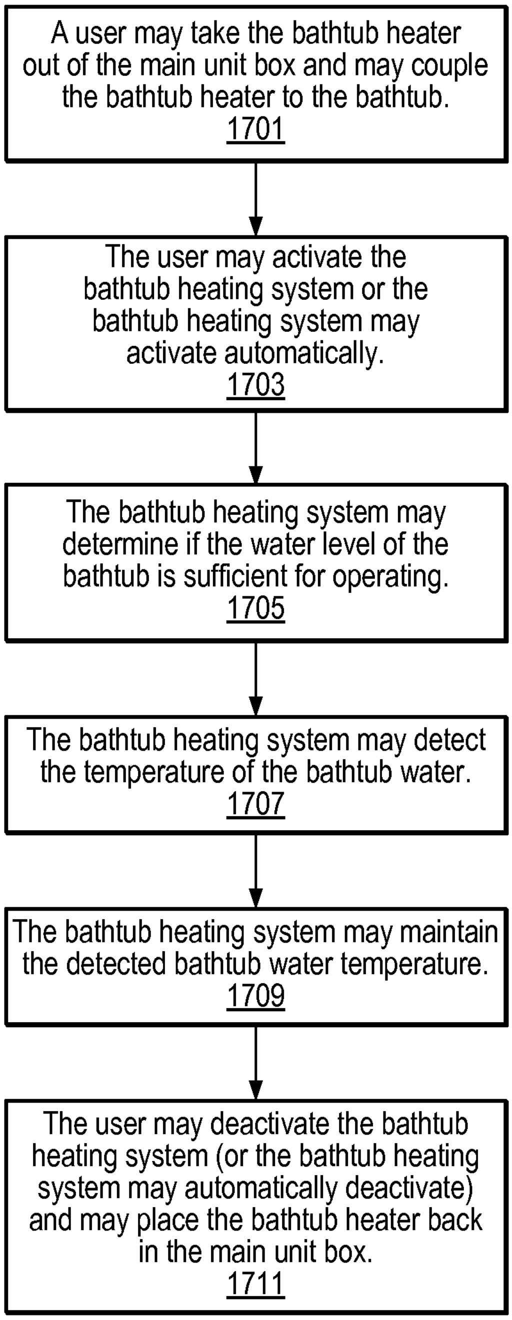

A user may take the bathtub heater out of the main unit box and may couple the bathtub heater to the bathtub.
1701
The user may activate the bathtub heating system or the bathtub heating system may activate automatically.
1703
The bathtub heating system may determine if the water level of the bathtub is sufficient for operating.
1705
The bathtub heating system may detect the temperature of the bathtub water.
1707
The bathtub heating system may maintain the detected bathtub water temperature.
1709
The user may deactivate the bathtub heating system (or the bathtub heating system may automatically deactivate) and may place the bathtub heater back in the main unit box.
1711

FIG. 17

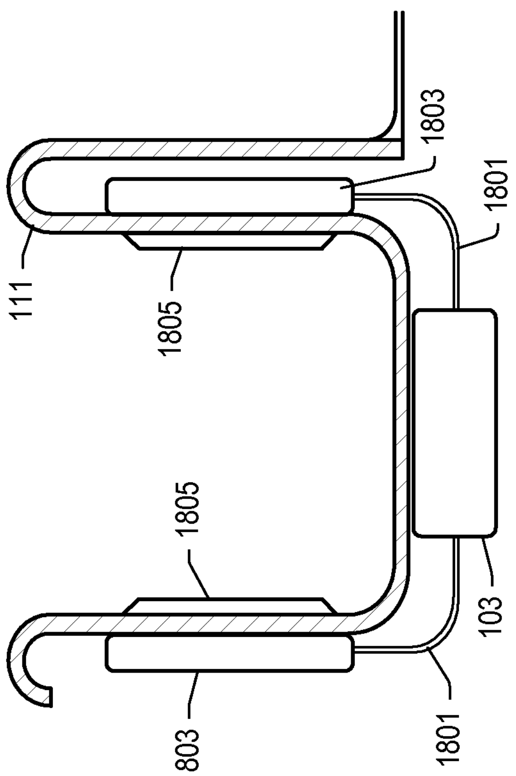


FIG. 18a

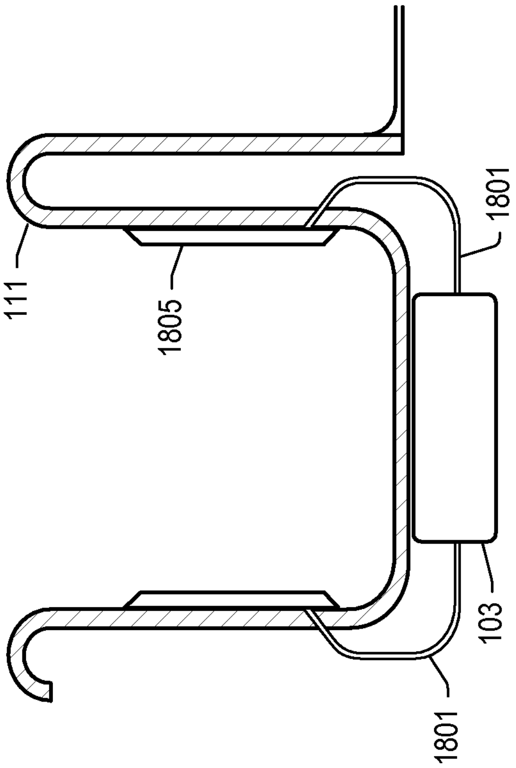


FIG. 18b

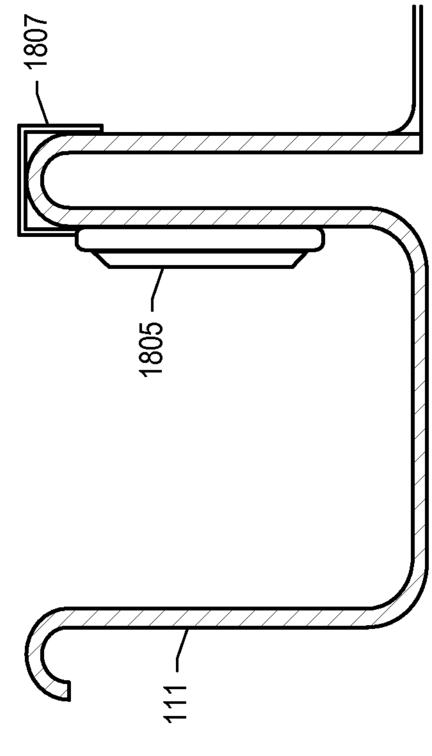


FIG. 18c

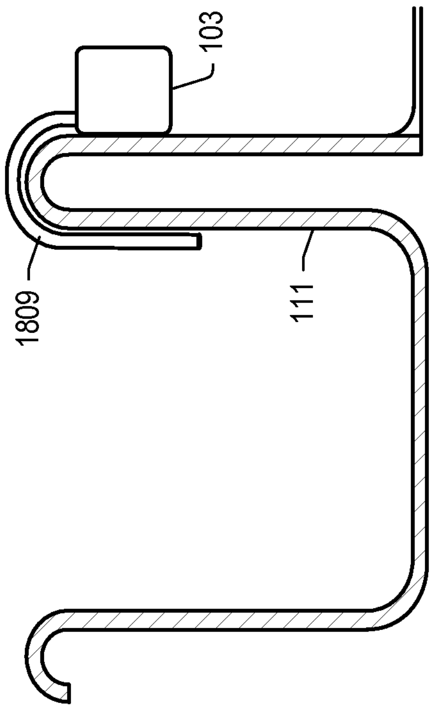


FIG. 18d

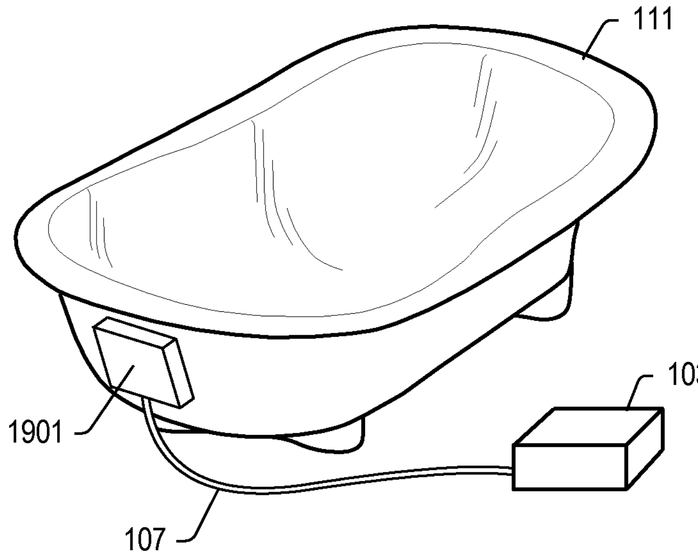


FIG. 19a

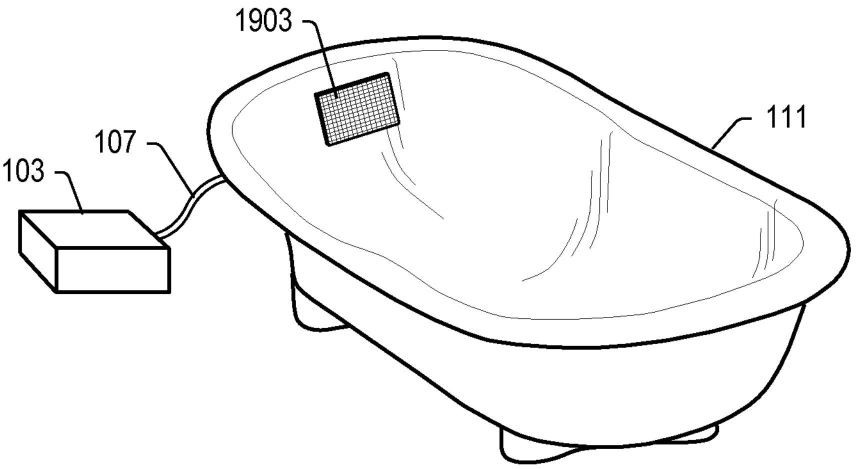


FIG. 19b

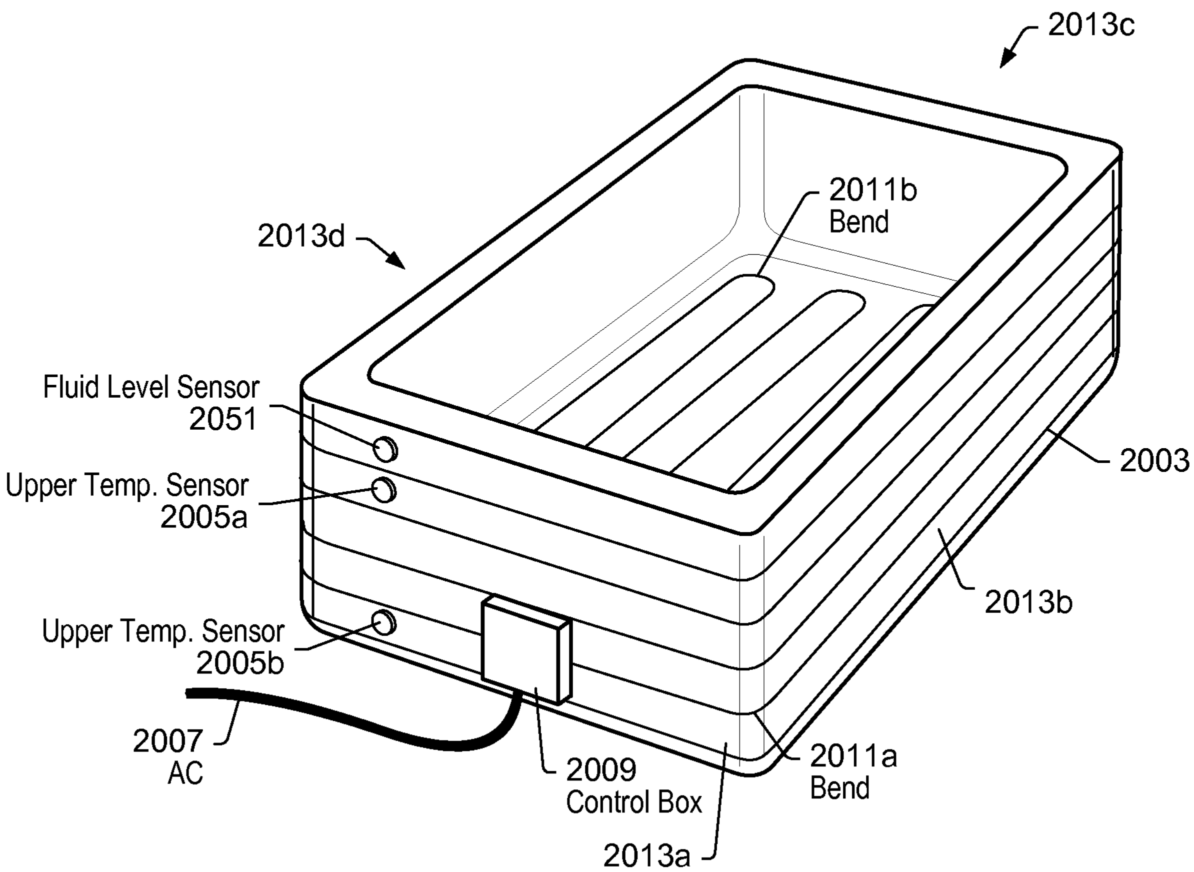


FIG. 20A

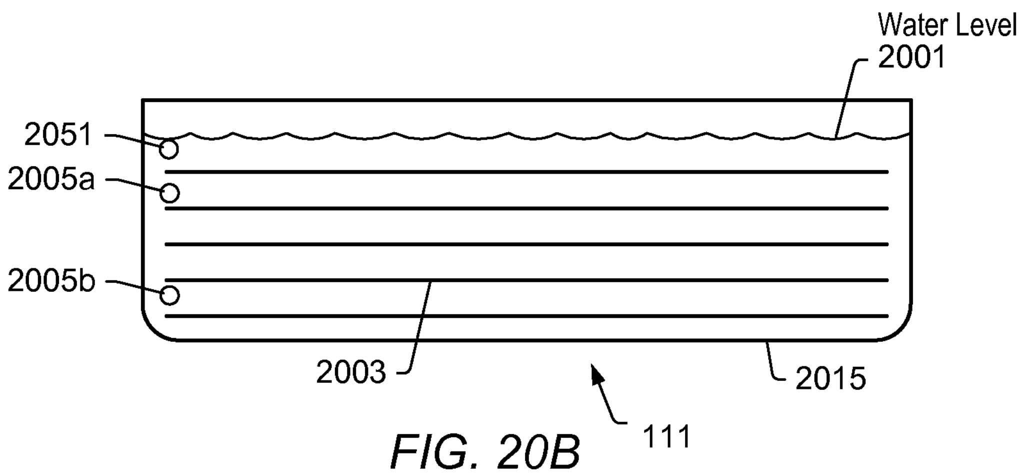


FIG. 20B

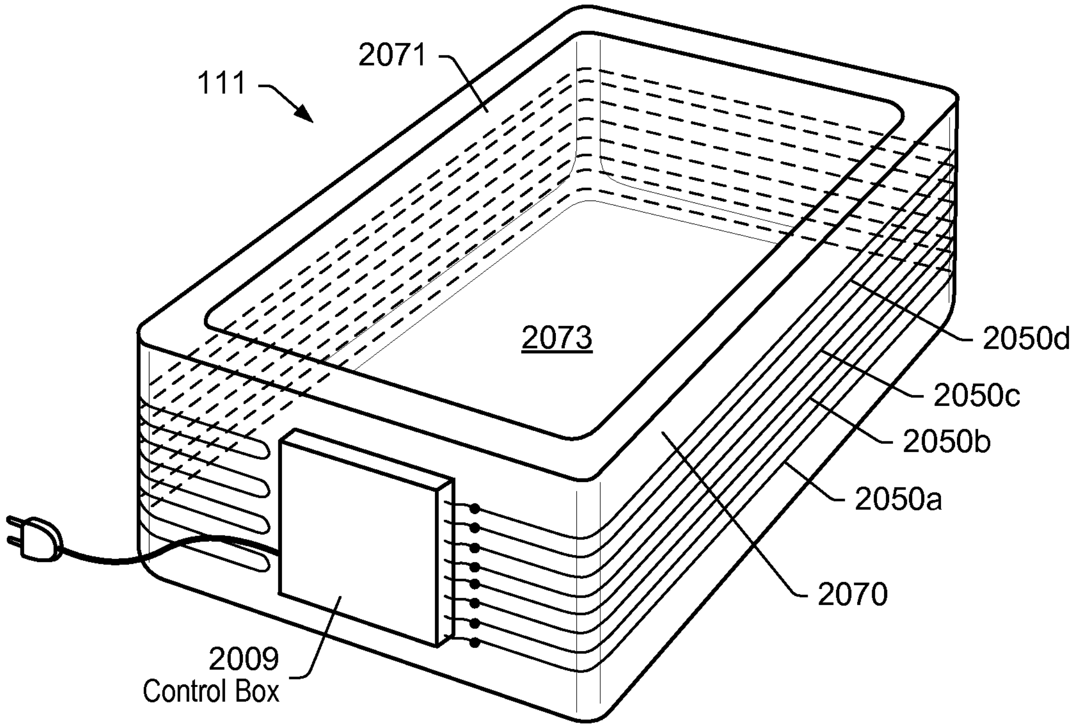


FIG. 20c

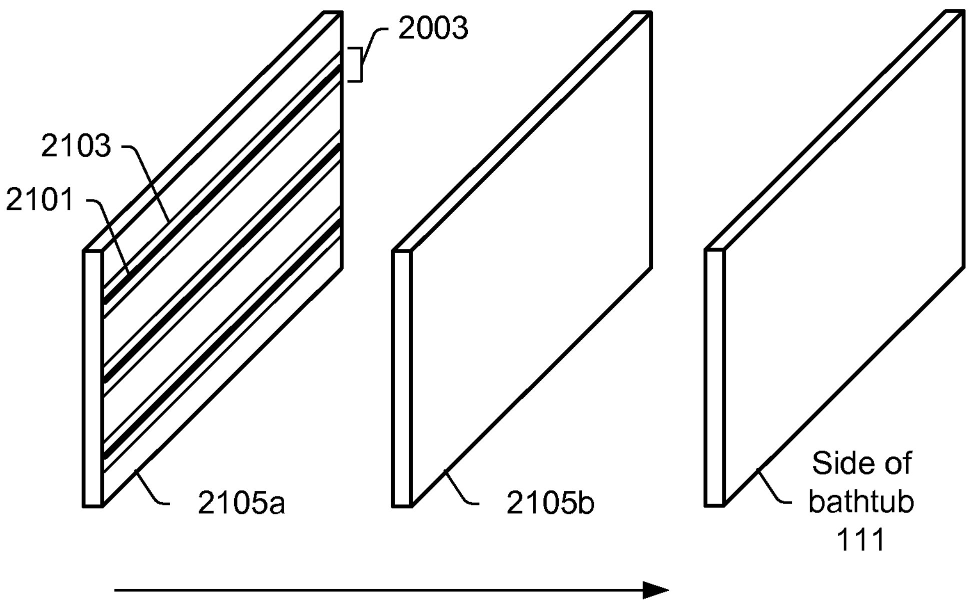

2003
2103
2101
2105a
2105b
Side of bathtub 111

FIG. 21

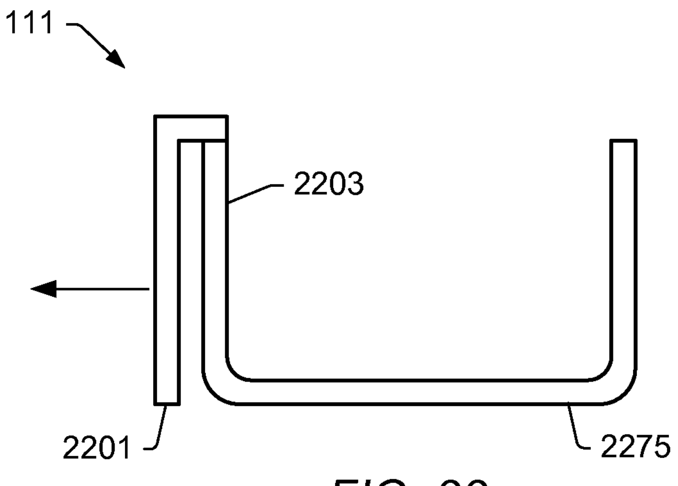

111
2203
2201
2275

FIG. 22

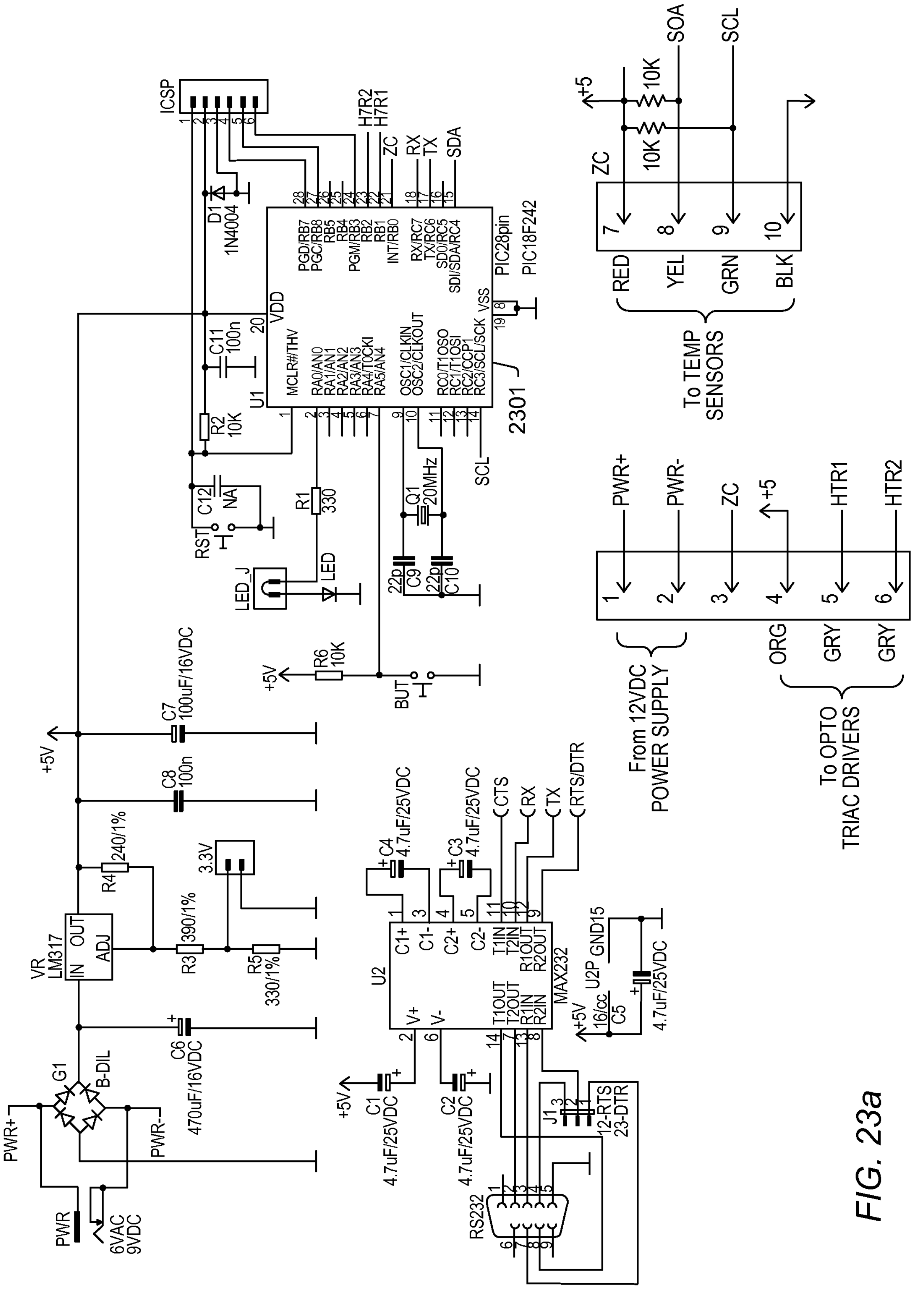

ICSP
PIC28pin
PIC18F242
U1
2301
D1
1N4004
C11
100n
R2
10K
RST
C12
NA
R1
330
LED
LED_J
Q1
20MHz
C9
C10
22p
R6
10K
+5V
BUT
VR
LM317
R4
240/1%
R3
390/1%
R5
330/1%
3.3V
C7
100uF/16VDC
C8
100n
C6
470uF/16VDC
G1
B-DIL
PWR+
PWR-
PWR
6VAC
9VDC
U2
MAX232
C1
C2
C3
C4
C5
4.7uF/25VDC
CTS
RX
TX
RTS/DTR
J1
12-RTS
23-DTR
RS232
To TEMP
SENSORS
RED
YEL
GRN
BLK
SOA
SCL
ZC
From 12VDC
POWER SUPPLY
To OPTO
TRIAC DRIVERS
HTR1
HTR2
ORG
GRY

FIG. 23a

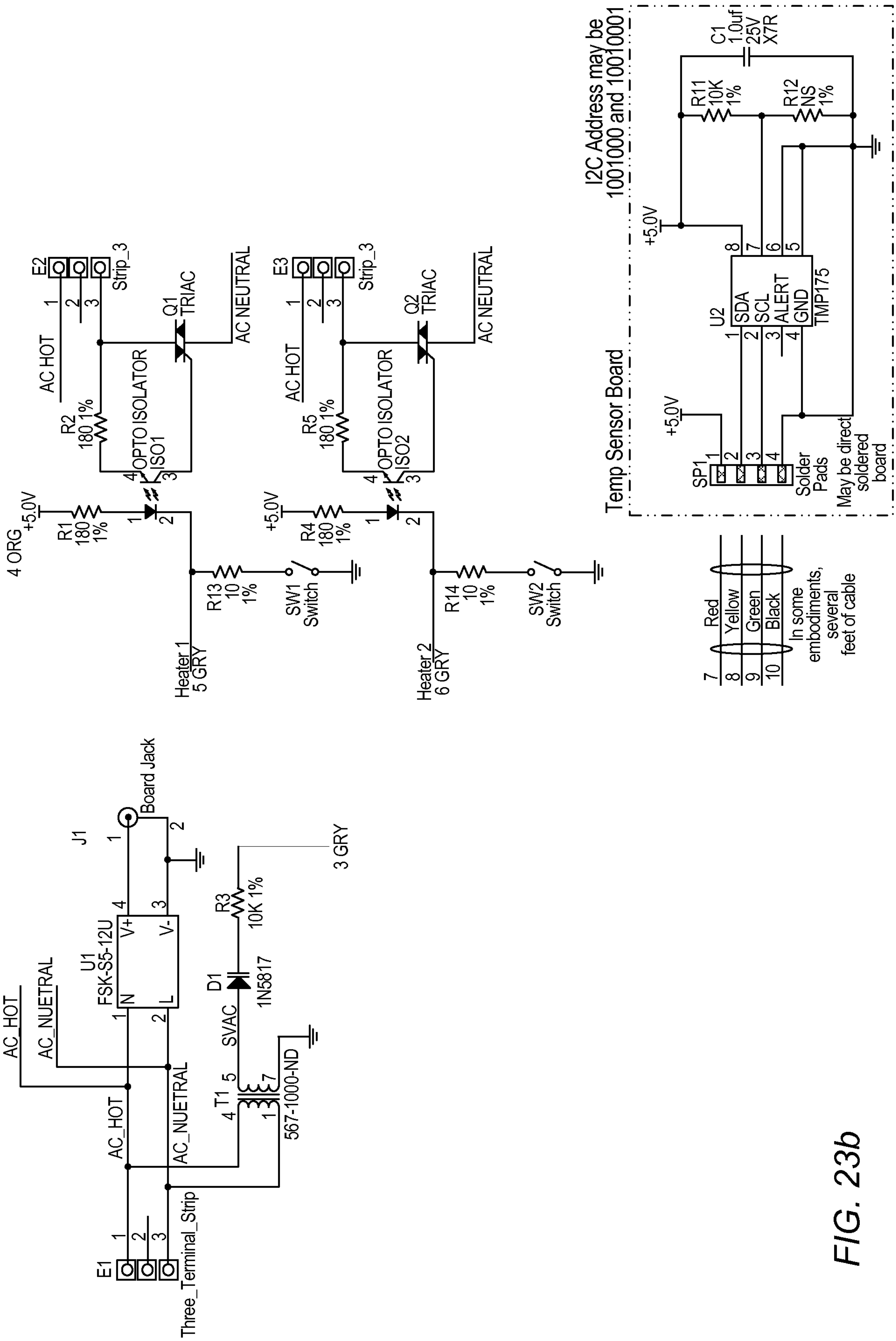
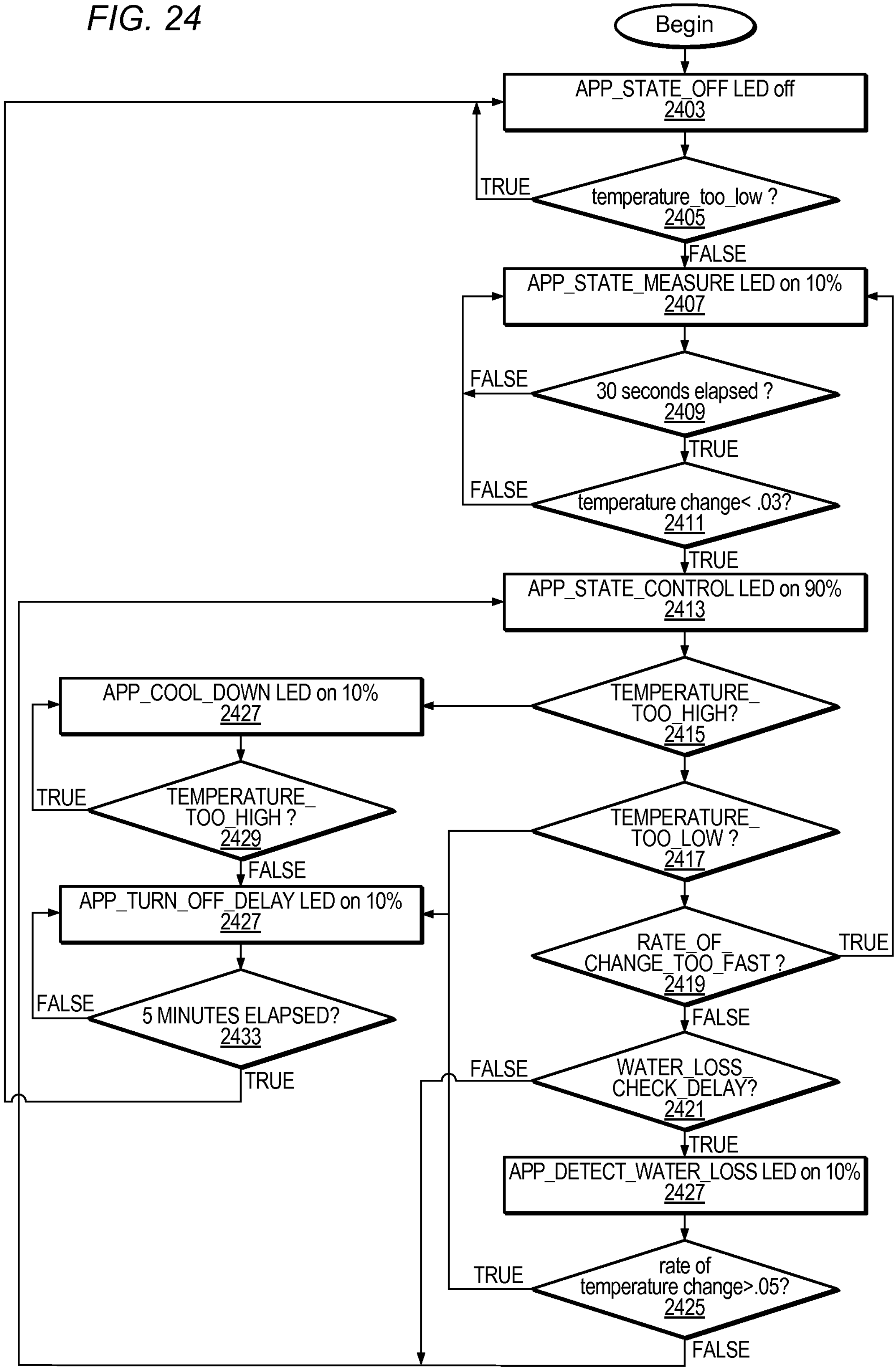

E1
Three_Terminal_Strip
AC_HOT
AC_NUETRAL
U1
FSK-S5-12U
V+
V-
J1
Board Jack
T1
567-1000-ND
SVAC
D1
1N5817
R3
10K 1%
3 GRY
4 ORG
+5.0V
R1
180
1%
OPTO ISOLATOR
ISO1
R2
180 1%
AC HOT
E2
Strip_3
Q1
TRIAC
AC NEUTRAL
R13
10
1%
SW1
Switch
Heater 1
5 GRY
R4
180
1%
ISO2
R5
180 1%
E3
Q2
R14
SW2
Heater 2
6 GRY
Temp Sensor Board
I2C Address may be
1001000 and 1001001
C1
1.0uf
25V
X7R
R11
10K
R12
NS
U2
SDA
SCL
ALERT
GND
TMP175
SP1
Solder
Pads
May be direct
soldered
board
Red
Yellow
Green
Black
In some
embodiments,
several
feet of cable

FIG. 23b

FIG. 24


Begin
APP_STATE_OFF LED off
2403
TRUE
temperature_too_low ?
2405
FALSE
APP_STATE_MEASURE LED on 10%
2407
FALSE
30 seconds elapsed ?
2409
TRUE
FALSE
temperature change< .03?
2411
TRUE
APP_STATE_CONTROL LED on 90%
2413
APP_COOL_DOWN LED on 10%
2427
TEMPERATURE_
TOO_HIGH?
2415
TRUE
TEMPERATURE_
TOO_HIGH ?
2429
TEMPERATURE_
TOO_LOW ?
2417
FALSE
APP_TURN_OFF_DELAY LED on 10%
2427
RATE_OF_
CHANGE_TOO_FAST ?
2419
TRUE
FALSE
5 MINUTES ELAPSED?
2433
FALSE
TRUE
FALSE
WATER_LOSS_
CHECK_DELAY?
2421
TRUE
APP_DETECT_WATER_LOSS LED on 10%
2427
TRUE
rate of
temperature change>.05?
2425
FALSE

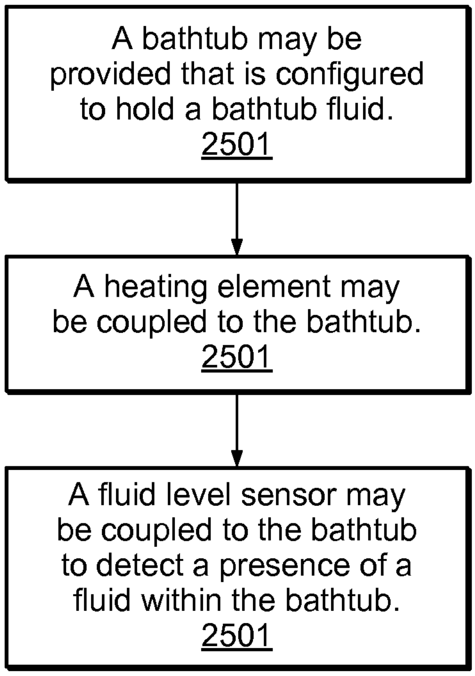

A bathtub may be provided that is configured to hold a bathtub fluid.
2501
A heating element may be coupled to the bathtub.
2501
A fluid level sensor may be coupled to the bathtub to detect a presence of a fluid within the bathtub.
2501

FIG. 25