(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 April 2012 (19.04.2012)

PCT

(10) International Publication Number
WO 2012/051276 A1

(51) International Patent Classification: *A61H 31/02* (2006.01)

(21) International Application Number: PCT/US2011/055935

(22) International Filing Date: 12 October 2011 (12.10.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data: 61/392,861 13 October 2010 (13.10.2010) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: HEAT PUMP BASED SPA HEATING AND COOLING METHOD AND APPARATUS

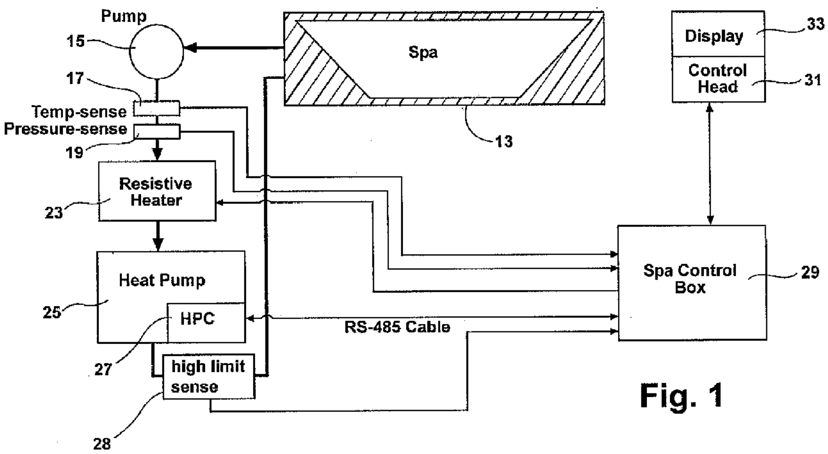

Fig. 1

(57) **Abstract**: A method of heating and cooling spa water comprising the steps of providing a heat pump operable in heating and cooling modes in a spa water circulation path, providing an electrical resistance heater in the circulation path, operating the electrical resistance heater concurrently with the heat pump in heating mode to heat the spa water to a threshold temperature which is, for example, within a selected number of degrees of a user-set temperature, disabling operation of said electrical resistance heater when said set threshold is reached, and thereafter heating the spa water to the user-set temperature using only the heat pump in heating mode as long as said temperature remains above said threshold.

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HEAT PUMP BASED SPA HEATING AND COOLING METHOD AND APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Application Serial No. 61/392,861, filed October 13, 2010, entitled, "Heat Pump Based Spa Heating and Cooling Method and Apparatus," the contents of which are incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

Field of Invention

[0002] The subject disclosure relates to spas, portable spas, hot tubs and the like and more particularly to a heat pump based spa heating and cooling method and apparatus.

RELATED ART

[0003] Portable spas have become quite popular as a result of their ease of use and multiplicity of features such as varied jet and seating configurations. One area where the inventors have recognized that enjoyment of portable spas could be enhanced is the area of implementing energy savings thereby reducing cost of operations of the spa.

SUMMARY

[0004] The following is a summary description of illustrative embodiments of the invention. It is provided as a preface to assist those skilled in the art to more rapidly assimilate the detailed design discussion which ensues and is not intended in any way to limit the scope of the claims which are appended hereto in order to particularly point out the invention.

[0005] In one embodiment, an illustrative heat pump based spa heating and cooling system may comprise a spa heat pump device with an electronic heat pump controller ("HPC"), a spa controller comprising one or more microprocessors and/or microcontrollers, and a spa control head with a user interface having an integrated display and key inputs, which may be built into the spa or comprise a remote control unit. In one embodiment, the HPC and spa controller each have an RS 485 interface to facilitate data communication between the two units.

[0006] The system allows a spa user to select a desired temperature from the spa control head or remote control system and select the operating mode of the spa heat pump system. The system translates these selections into heat pump commands and sends the commands via the RS-485 bus or other communication path from the control head to the HPC. The HPC then operates the heat pump in either a heat or a chill mode to warm or cool the spa water. A resistance heater may also be used in conjunction with the heat pump for rapid heating, or as a backup. In one embodiment, the control system identifies the presence of the HPC and enables presentation of control selection screens through the main control panel or remote control.

[0007] In an illustrative embodiment, spa water flows through a conventional resistance heater and then through a heat exchanger coil, which either heats the water or cools the water as may be necessary to maintain a temperature set by the user. Alternatively, the water may flow first through the heat exchanger and then through the conventional resistance heater. In such embodiments, the resistance heater is used as a "boost" heater and only participates in heating the water until the water temperature is within a fixed number of degrees of the user-set temperature. At that point, the boost heater ceases functioning and the heat pump applies the heat necessary to reach the set temperature. Thus, during start-up, the heat pump participates in heating the water simultaneously with the boost heater, thus causing the water to heat faster than if the boost heater were used alone. After the heat pump and resistance heater cause the set temperature to be reached, only the heat pump is used to maintain the set temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a system block diagram of an illustrative heat pump based spa heating and cooling system embodiment;

[0009] Fig. 2 is a front view of an example of a user interface which may be employed in the embodiment of Fig. 1;

[0010] Fig. 3 is a schematic sectional diagram of one embodiment of a heat exchanger employable in the embodiment of Fig. 1;

[0011] Fig. 4 is a schematic perspective diagram of an alternate heat exchanger embodiment;

[0012] Fig. 5 is a logic diagram illustrative of logic employed by the spa controller of Fig. 1;

[0013] Fig. 6 is a schematic diagram illustrating one embodiment of a spa controller employable in the embodiment of Fig. 1; and

[0014] Fig. 7 is a schematic front view illustrating an embodiment of a user interface for implementing various temperature control functions in an embodiment such as that of Fig. 1.

DETAILED DESCRIPTION

[0015] Fig. 1 illustrates one embodiment of a heat pump based spa heating and cooling system. In this system, water is circulated through a water circulation path. Water circulation may be intermittent or continuous in various embodiments. For example, in one embodiment, water circulation may be used intermittently when heat is required.

[0016] In the water circulation path shown in Fig. 1 are a spa tub 13, a circulation pump 15, and temperature sensors, which may include a regulating temperature thermistor 17, whose value is used by a control system 29 to regulate water temperature, and a high-limit thermistor 28, whose value is used to shut off heater operation if the spa water temperature exceeds, for example, 120°F. The system of Fig. 1 further includes a pressure (flow) sensor 19 to sense proper water flow, a resistive heater 23 and a heat pump 25 and associated Heat Pump Controller (HPC) 27. The HPC 27 operates in response to commands from the spa controller 29, which interfaces with a control head 31, which includes a user interface 33.

[0017] An illustrative user interface 33 is shown in Fig. 2. The interface or control panel 33 includes four outer "hard" control buttons 351, 352, 353, 354 and four inner "soft" buttons 355, 356, 357, 359. In one embodiment, the four outer control buttons 351, 352, 353, 354 comprise, respectively, a spa jets control button, a lights control button, a "back" button, and an "options" button. Each soft control button 351, 352, 353, 354 effects changes depicted visually in an area of the display screen 349 adjacent the particular soft control button. An icon bar 360 is located below the display screen 349 and includes a water care icon 361 which may be illuminated when a salt water sanitizing system is installed. The icon flashes 361 when the system requires attention. Figure 2 illustrates a screen display on the display panel 349 after the "options" button 354 has been depressed and "Water Care" has been selected from one of the options displayed by depressing the appropriate "soft button".

[0018] In one embodiment, the heat pump 25 may be split into (a) a condenser/fan/compressor unit, and (b) a separate heat exchanger mounted within the spa skirt. Alternatively, the condenser, fan, compressor, and heat exchanger may all be located outside the spa 13, in which case a water circulation supply line runs outside the spa 13 to the heat pump 25 and a water circulation return line runs from the heat pump 25 back to the spa 13. In one embodiment, the system may provide a "Boost mode" wherein the resistive heater 23 is turned on simultaneously with the heat pump 25 to rapid-heat the spa 13 if the difference between the water temperature and the desired temperature is greater than, for example, 3 degrees.

[0019] In one embodiment, system temperature limiting is performed by the spa controller 29, based on the high limit thermistor 28. In this embodiment, the decision to shut down due to excessive temperature is also made by the spa controller 29, which sends appropriate commands to the Heat Pump Control 27 to stop the heat pump 25 from operating. In addition, the operation of the heat pump 25 is stopped if any one of a number of errors in the system are detected, such as, for example, no water circulation, failure of RS-485 communication, or internal heat pump errors. Thus, the heat pump 25 operates as a slave to the control system comprising the controller 29 and control head 31 (or remote) and performs no temperature regulation on its own. In another embodiment, the temperature limiting and shut down functions could be implemented in the control head 31.

[0020] In one embodiment, the heat pump 25 includes the HPC electronic module 27, which controls local heat pump internal devices and communicates with the spa controller 29 to receive commands and for error reporting. The heat pump 25 may comprise a standard heat pump system including:

(a) A heat exchanger 35 (e.g., Fig. 3) to transfer heat between the heat pump refrigerant and the spa water, and

(b) A compressor-condenser-fan unit for exchanging heat with the surrounding air and providing heated refrigerant to the heat exchanger.

The heat exchanger 35 may be a separate unit within the spa 13 (split design) as shown in Fig. 3, or part of the compressor-condenser unit (mono-block design) as shown in Fig. 4. In either design, the heat exchanger 35 may comprise a single coil 36 helically or otherwise shaped and disposed around the water flow path 37 as shown in Fig. 3. A typical heat pump 25 may provide a power output of 3500 watts, a coefficient of Performance (COP) of 3 to 4 at an operating voltage of 230 VAC. One monoblock embodiment may measure 31 x 14 x 22 inches.

[0021] An embodiment with an under-the-skirt heat exchanger, where the compressor and condenser are located outside the spa 13, is more efficient since water does not continually circulate outside the spa 13 to the heat pump unit. Water freezing problems are also avoided. The heat pump 25 may also be conveniently located in the step of the spa 13 or in other spa-coordinated housing or may be attached to a spa sidewall.

[0022] The communication link between the spa 13 and heat pump 25 may be an RS-485 serial link as discussed above, a wireless data link such as Zigbee radio, or other form of communication. In one embodiment, serial communication of heat pump control commands by the spa controller 29 to the "slave" heat pump controller 27 is employed. The system also reports errors back to the spa controller from the heat pump.

[0023] In one embodiment, handshaking, status checks, and timeouts between the spa control 29 and the heat pump 25 may be employed to verify that the heat pump 25 is operational and is performing the requested tasks. For example, data packets may be sent to the HPC 27, which include a check sum that must be valid for the HPC 27 to accept a command to heat. Such operation provides a safety feature to ensure that the water temperature remains within the proper range and that the heat pump 25 does not just keep running if communication fails. Temperature sensors in the spa 13 are also used to govern the operation of heat pump 25, as opposed to the heat pump 25 having its own sensors in the heat exchanger. In one embodiment, a dedicated fault wire connection may also be employed, whereby the output signal from the spa control's hardware fault circuitry is also directly sent to the heat pump 25. In one embodiment, this may be a signal from a high temperature limit detection circuit. The output of that circuit is then sent over a single dedicated wire to the heat pump 25 to force it to shut down in the event of software failure within either the spa control 29 or the heat pump control 27.

[0024] Various embodiments may also employ control logic for determining concurrent and non-concurrent operation of the heat pump 25, resistive heater 23, and jet pumps (not shown) with the objective of assuring that electric circuits are not overloaded. The concurrency mode is selected according to the type of spa, the number of pumps, the heater wattage, and the nature of the electrical wiring. For example, if concurrent operation of the jet pumps and heat pump 25 are not allowed, the heat pump 25 will be shut off when a jet pump is activated by the user, so that the spa would only heat via the resistive heater 23 while the pumps are on. Non-concurrent operation of the jet pumps and the resistive heater is typically required for operation from single circuit power, or if a third jet pump and heater share the same circuit. Other embodiments may provide for programmable operation for specific time periods during the day to avoid peak-electric charges. Remote system control and monitoring of the heat pump 25 via an internet-enabled spa may also be provided, including the ability, for example, to modify cycling of the heat pump 25 remotely based on hourly electric rates.

[0025] Logic for implementing control of the heat pump 25 and resistance heater 23 according to an illustrative embodiment is shown in Fig. 5. In the illustrative embodiment, such logic, as well as other logic discussed herein, is embodied in one or more computer programs or computer software. In one embodiment shown in Fig. 6, such software is stored on a computer readable medium or media 63 and is executed by a microprocessor 61, or one or more microprocessors, or other computer(s) or microcontroller(s). Apparatus for executing such instructions may comprise part of either the spa controller 29 or the control head 31, or both, in various embodiments. In other embodiments, logic such as that shown in Fig. 5 may be hard-wired.

[0026] For the purposes of this disclosure, a computer readable medium stores computer data, which data can include computer program code that is executable by a computer, in machine readable form. By way of example, and not limitation, a computer readable medium may comprise computer readable storage media, for tangible or fixed storage of data, or communication media for transient interpretation of code-containing signals. Computer readable storage media, as used herein, refers to physical or tangible storage (as opposed to signals) and includes without limitation volatile and non-volatile, removable and non-removable storage media implemented in any method or technology for the tangible storage of information such as computer-readable instructions, data structures, program modules or other data. Computer readable storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other physical or material medium which can be used to tangibly store the desire information or data or instructions and which can be accessed by a computer or processor.

[0027] In various embodiments, when suitable computer program code implementing logic as taught herein is loaded into and executed by a computer, the computer becomes a specially configured apparatus. Various forms of computer program code may be used, for example, whether stored in a storage medium, loaded into and/or executed by a computer, or transmitted over some transmission medium, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation.

[0028] According to the logic of Fig. 5, respective comparisons are made at first and second comparator blocks 51, 53. The first comparator 51 compares the detected water temperature to a threshold temperature represented at block 55, which is, for example, three degrees below the desired user-selected temperature. This threshold temperature may be inputted by the user at the control panel 33. The second comparator 53 compares the detected water temperature to the user-selected temperature setting. If a water heating mode is selected, the second comparator 53 generates a command to turn the heat pump 25 on in heating mode. If a cooling mode is selected, the second comparator 53 generates a command to the heat pump 25 to turn on and operate in cooling mode, for example, if the detected water temperature is two degrees above the user selected (user "set") temperature (block 56). In some embodiments, the threshold temperature at block 55 and other temperature range selections, may be fractional degrees, e.g., 2.5 degrees in addition to integer multiples.

[0029] The first comparator 51 also implements a "boost" function in the illustrative embodiment. In particular, if "boost mode" is enabled and the detected water temperature is three degrees below the user selected temperature, the "AND" function represented by logic gate 54 is satisfied and the electrical resistance heater 23 is turned on. Once the detected water temperature rises above the three degree limit, the electrical resistance heater 23 is disabled. Thus, during initial start-up heating of the spa 13, both the electrical resistance heater 23 and heat pump 25 operate simultaneously to heat the water more rapidly than could be achieved by either unit 23, 25 acting alone. Once, the three degree limit is reached, the electrical resistance heater 23 turns off, allowing the heat pump 25 alone to heat the water to the user selected temperature. Thereafter, the heat pump 25 alone maintains the water temperature at the user selected temperature, thereby achieving the efficiency and energy savings inherent in the operation of heat pump 25. In the embodiment shown in Fig. 4, it will be appreciated that, if "boost mode" is not selected, the electrical resistance heater 23 will not operate at all.

[0030] A temperature screen/soft key format for a control display such as shown in Fig. 3 is illustrated in Fig. 7. The display of Fig. 7 comprises soft keys 201, 203, 205, 207, which respectively set the mode of the temperature control, Fahrenheit or Centigrade Lock function, and further permit setting the user desired temperature either "up" or "down". Definitions for operation according to another illustrative control logic embodiment is set forth in the following table.

[0031] Soft key Definitions

Each soft key press selects the next sequential function for that key.

Key	Display	Function

MODE Key 201	Heat- w/Boost	1) When water temperature is <= set temperature – offset_1, start heat pump in heat mode. 2) If water temperature is <= set temperature – offset_2, turn on resistive heater simultaneously with heat pump. Offset_1 = 0.5 degrees F Offset_2 = 3.0 degrees F
	Heat- Saver	When water temperature is <= set temperature – offset_1, start heat pump in heat mode. Keep resistive heater off.
	Chill	When water temperature is >= set temperature + offset_3, start heat pump in chill (cool) mode. Resistive heater off except in HP fault condition. Offset_3 = 2.0 degrees F
	Auto- w/Boost	1) When water temperature is <= set temperature – offset_1, start heat pump in heat mode. 2) If water temperature is <= set temperature – offset_2, turn on resistive heater simultaneously with heat pump. 3) When water temperature is >= set temperature + offset_3, start heat pump in chill (cool) mode.

		Offset_1 = 0.5 degrees F Offset_2 = 3.0 degrees F Offset_3 = 2.0 degrees F
	Auto- Saver	1) When water temperature is <= set temperature – offset_1, start heat pump in heat mode. 2) Resistive heater remains off at all times, except in HP fault condition. 3) When water temperature is >= set temperature + offset_3, start heat pump in chill (cool) mode. Offset_1 = 0.5 degrees F Offset_3 = 2.0 degrees F
F/C/Lock Key 203	°F- unlocked	Display temperatures in degrees Fahrenheit, Allow temperature changes.
	°F- temperature lock	Display temperatures in degrees Fahrenheit, Disallow all temperature changes.
	°C- unlocked	Display temperatures in degrees Celsius, Allow temperature changes.
	°C- temperature lock	Display temperatures in degrees Celsius, Disallow all temperature changes.
Temp Up Key 205	<<up arrow>>	Increment set temperature if unlocked. Range 80°F to 104°F. Press and hold to increment to 105°F & 106°F (Safety).
Temp Down Key 207	<<down arrow>>	Decrement set temperature if unlocked. Range 80°F to 104°F.

In one embodiment, the temperature reading or temperature setting is displayed in the center of the display in "F" or "C" format. In one embodiment, the set temperature display changes to a red color if the set temperature is at the 105 or 106 degree F setting.

[0032] Those skilled in the art will appreciate that various adaptations and modifications of the just described preferred embodiment can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

CLAIMS

1. A method of heating and cooling spa water comprising:

providing a heat pump operable in heating and cooling modes in a spa water circulation path;

providing an electrical resistance heater in said circulation path;

operating the electrical resistance heater concurrently with the heat pump in heating mode to heat the spa water to a threshold temperature which is within a selected number of degrees of a user-set temperature; and

disabling operation of said electrical resistance heater when said set threshold is reached and thereafter heating the spa water to the user-set temperature using only the heat pump in heating mode.

2. The method of claim 1 further comprising employing only the heat pump in heating mode to provide heating as necessary to maintain the user-set temperature after said threshold is reached.

3. The method of claim 1 wherein said threshold temperature is three degrees Fahrenheit below the user-set temperature.

4. The method of claim 1 wherein said threshold temperature is in the range of one to five degrees Fahrenheit below the user-set temperature.

5. The method of claim 1 wherein the heat pump is separated into a heat exchanger within the spa, and a compressor-condenser unit integrated with a spa step or spa wall.

6. The method of claim 1 wherein heat and cool logic is located in a spa control system and the heat pump comprises a controller responsive to that logic via a communications link.

7. The method of claim 1 wherein the electrical resistance heater may be selectively disabled.

8. Spa water heating apparatus comprising:

a heat pump operable in heating and cooling modes in a spa water circulation path;

an electrical resistance heater in said circulation path; and

a controller configured to:

(a) operate the electrical resistance heater concurrently with the heat pump in a heating mode to heat the spa water to a threshold temperature which is within a selected number of degrees of a user-set temperature; and

(b) disable operation of said electrical resistance heater when said set threshold is reached and thereafter heating the spa water to the user-set temperature using only the heat pump in heating mode.

9. The apparatus of claim 8 further comprising employing only the heat pump in heating mode to provide heating as necessary to maintain the user-set temperature after said threshold is reached.

10. The apparatus of claim 8 wherein said threshold temperature is three degrees Fahrenheit below the user-set temperature.

11. The method of claim 8 wherein said threshold temperature is in the range of one to five degrees Fahrenheit below the user-set temperature

12. The apparatus of claim 8 wherein the heat pump is separated into a heat exchanger within the spa, and a compressor-condenser unit integrated with a spa step or spa wall.

13. The apparatus of claim 8 wherein heat and cool logic is located in the spa control system and the heat pump comprises a controller responsive to that logic via a communications link.

14. The apparatus of claim 8 wherein the electrical resistance heater may be selectively disabled.

15. The apparatus of claim 8 wherein said controller comprises a programmed microprocessor or programmed microcontroller.

16. The apparatus of claim 8 wherein the heat pump is configured to detect one or more faults to stop heating or cooling based on failed communication with the spa control, or in response to receipt of an electrical hardware fault signal from the spa control, or in response to a specific instruction to shut down in the event of a fault in the spa control.

17. Computer software stored on a tangible computer readable medium and operable when executed by one or more computers or processors to:

(a) operate an electrical resistance heater concurrently with a heat pump in a heating mode to heat spa water to a threshold temperature which is within a selected number of degrees of a user-set temperature;

(b) detect when said threshold is reached; and

(c) disable operation of said electrical resistance heater upon detecting that said user-set threshold is reached and thereafter maintaining the spa water at the user-set temperature using only the heat pump in heating mode.

18. Spa water heating apparatus comprising:

a heat pump operable in heating and cooling modes in a spa water circulation path;

said heat pump employing fault detection to stop heating or cooling if one or more selected faults is or are detected;

an electrical resistance heater in said circulation path and a controller configured to:

(a) operate the electrical resistance heater concurrently with the heat pump in a heating mode to heat the spa water to a threshold temperature which is within a selected number of degrees of a user-set temperature; and

(b) disable operation of said electrical resistance heater when said set threshold is reached and thereafter heating the spa water to the user-set temperature using only the heat pump in heating mode.

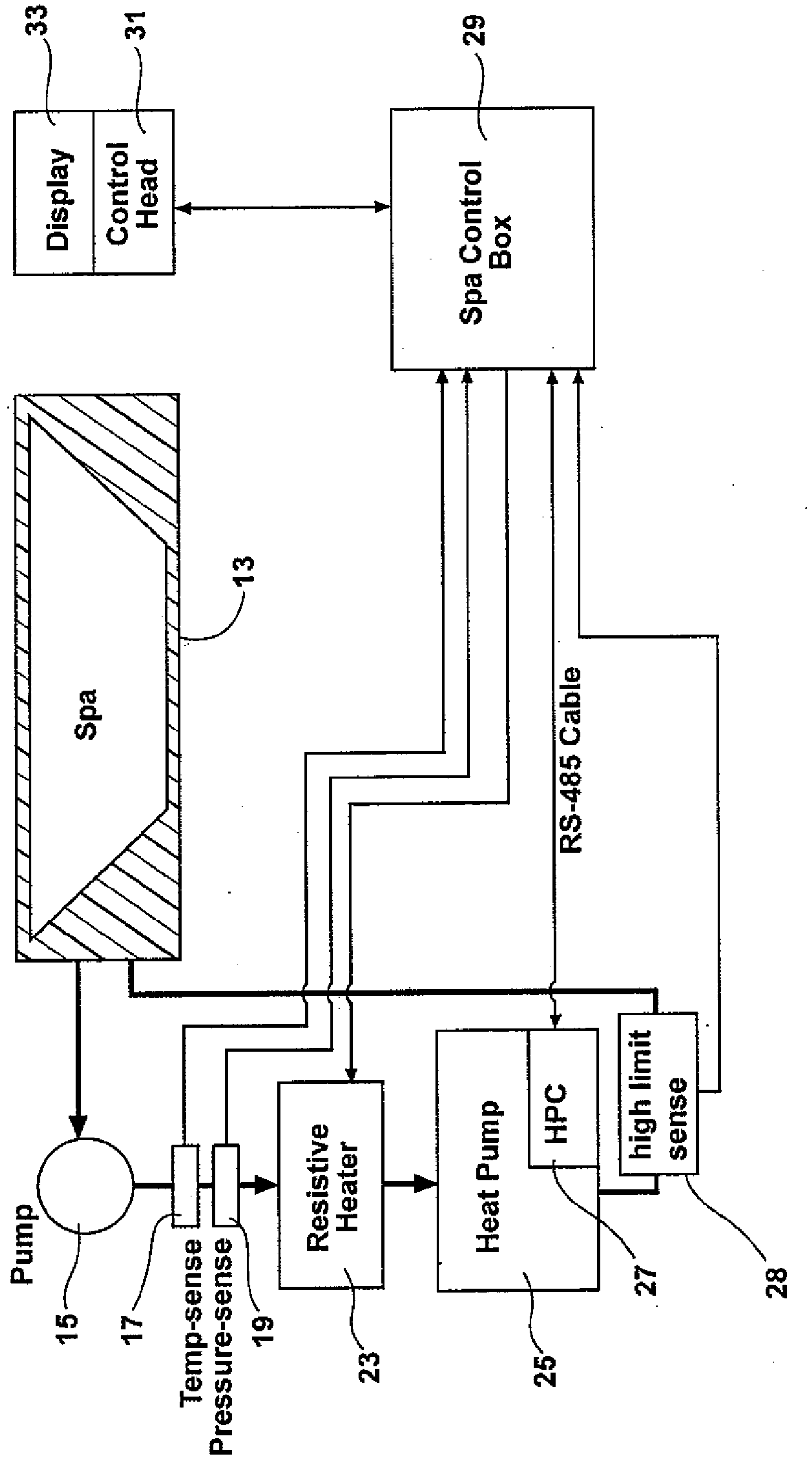

Display
Control Head
33
31
Spa Control Box
29
Spa
13
RS-485 Cable
Pump
15
Temp-sense
17
Pressure-sense
19
Resistive Heater
23
Heat Pump
25
HPC
27
high limit sense
28

Fig. 1

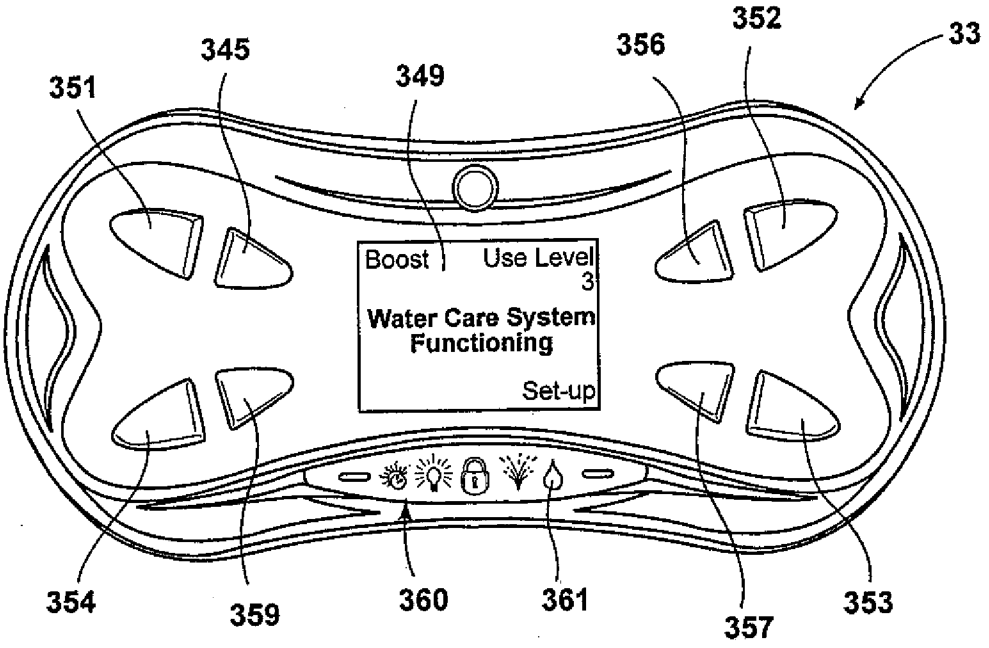

351
345
349
356
352
33
Boost
Use Level
3
Water Care System
Functioning
Set-up
354
359
360
361
357
353

Fig. 2

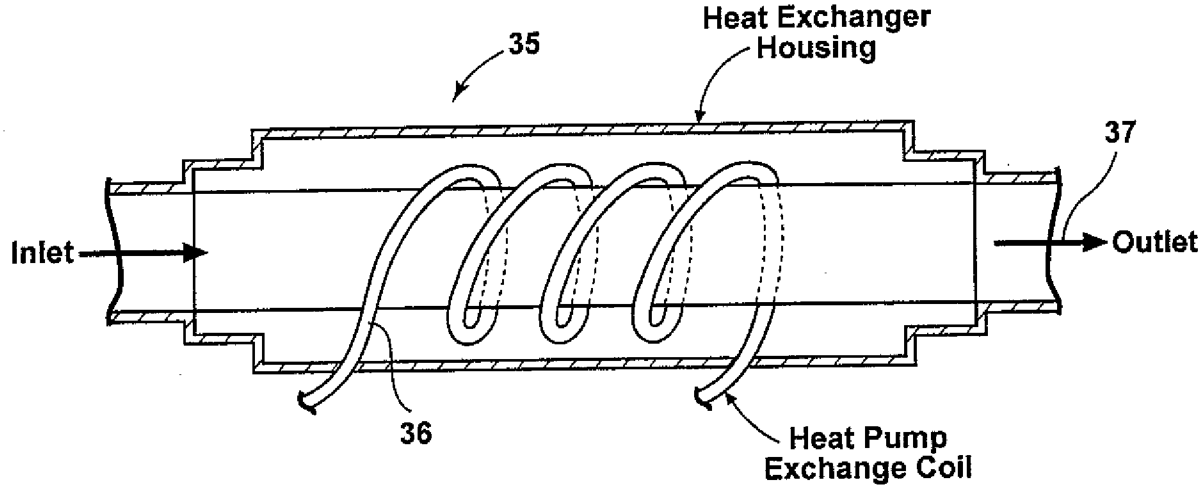

35
Heat Exchanger Housing
37
Inlet
Outlet
36
Heat Pump Exchange Coil

Fig. 3

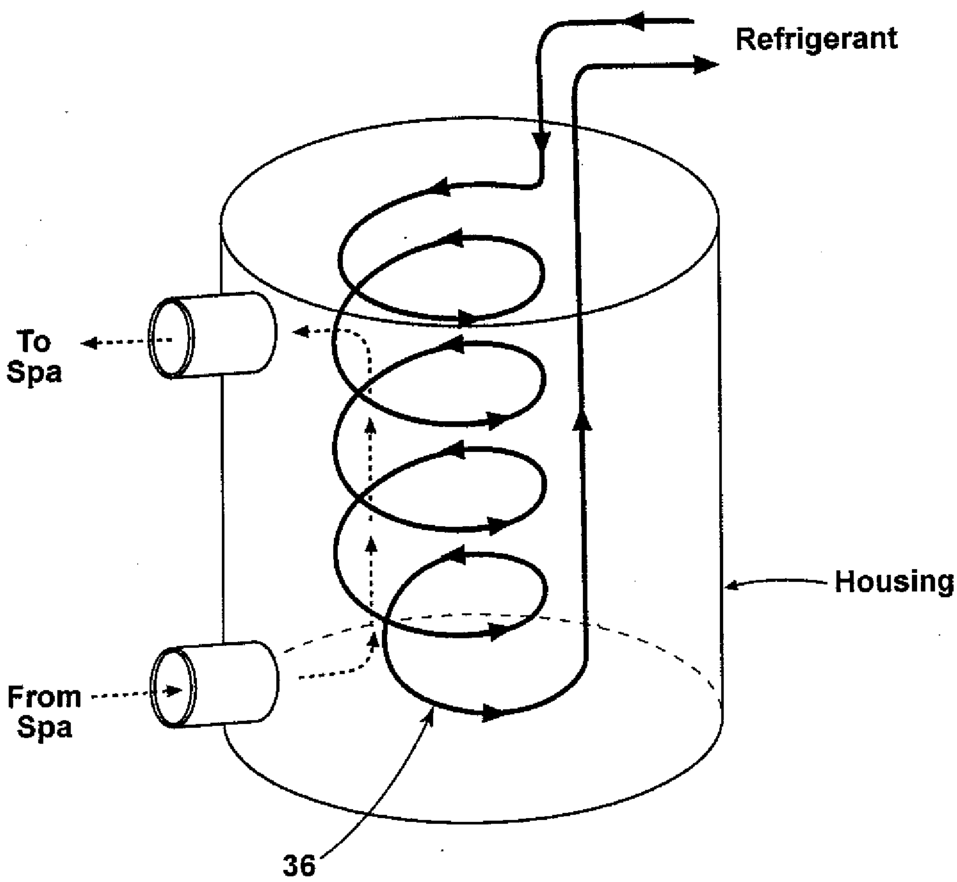

Refrigerant
To Spa
Housing
From Spa
36

Fig. 4

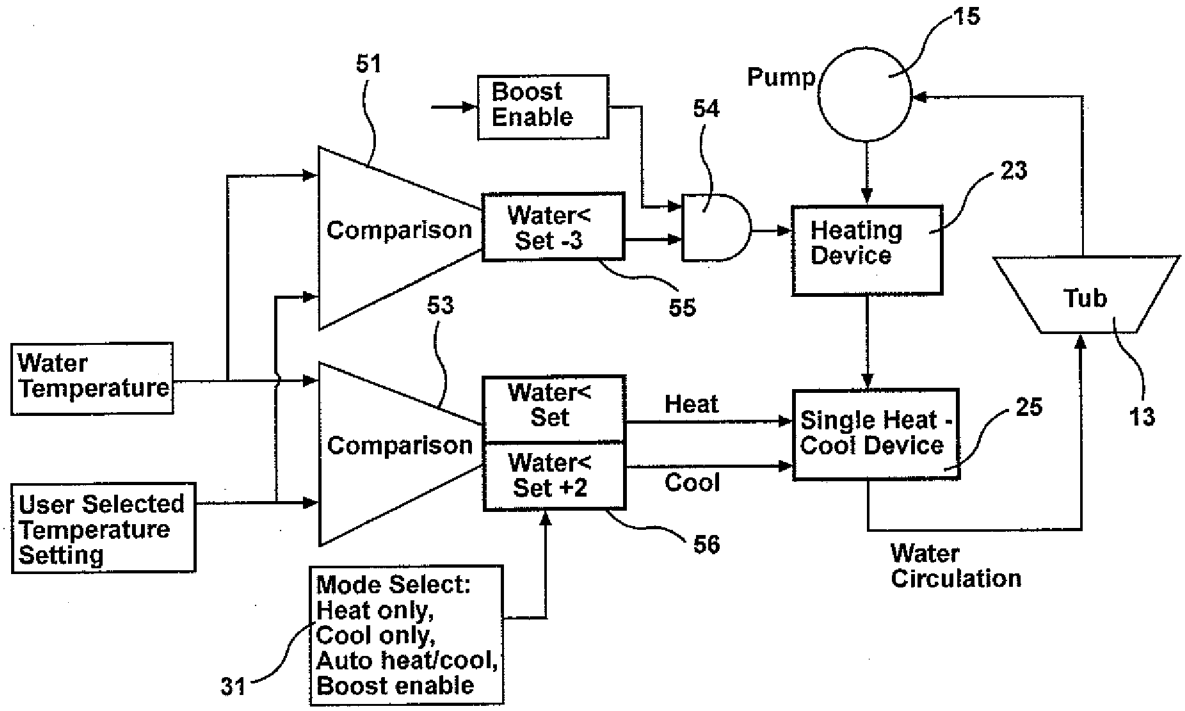
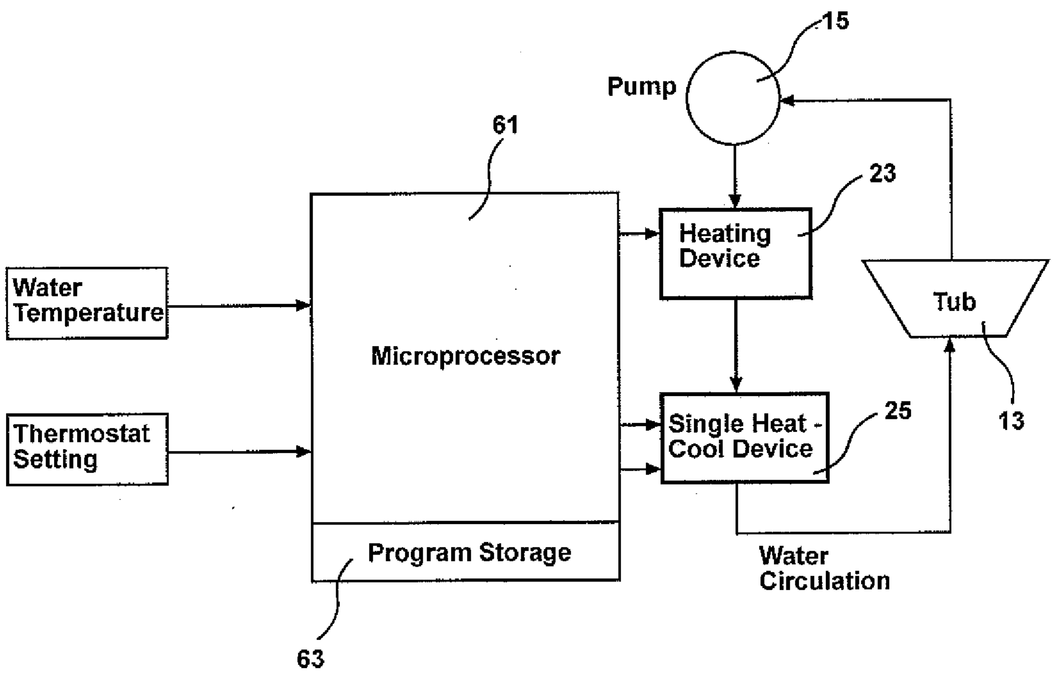

51
Boost Enable
54
15
Pump
Comparison
Water< Set -3
Heating Device
23
Tub
55
53
Water Temperature
Water< Set
Heat
Single Heat - Cool Device
25
13
Comparison
Water< Set +2
Cool
User Selected Temperature Setting
56
Water Circulation
Mode Select: Heat only, Cool only, Auto heat/cool, Boost enable
31

Fig. 5


15
Pump
61
23
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Tub
Water Temperature
Microprocessor
Thermostat Setting
Single Heat - Cool Device
25
13
Program Storage
Water Circulation
63

Fig. 6

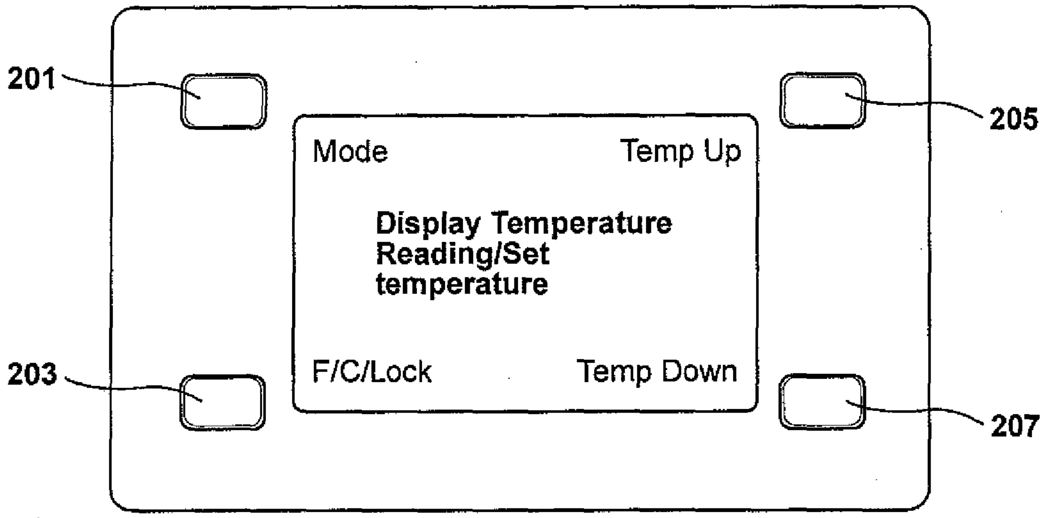
201
203
205
207
Mode
Temp Up
Display Temperature
Reading/Set
temperature
F/C/Lock
Temp Down

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/55935

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61H 31/02 (2012.01)
USPC - 4/545
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 4/545

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 4/538-540, 541.1, 541.2, 545, 546 *(keyword limited; terms below)*

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Thomson Innovation [USGrant, GB App, USApp, FR App, WO App, DE Util, EP Grant, DE Grant, EP App, DE App, JP Util, JP Grant, JP App, CN Util, CN App, KR Util , KR Grant, KR App]; Google Scholar; tub, pool, spa, whirlpool, heat pump , heater, electrical, threshold, limit, temperature

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2007/0180607 A1 (Pickrell et al.) 09 August 2007 (09.08.2007) para [0019], [0053]	1-15, 17 ------------ 16, 18
Y	US 2010/0132106 A1 (Cline et al.) 03 June 2010 (03.06.2010) para [0020]	16, 18
A	US 7,210,303 B2 (Zhang et al.) 01 May 2007 (01.05.2007) entire doc	1-18
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☐ Further documents are listed in the continuation of Box C. ☐

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Date of the actual completion of the international search	Date of mailing of the international search report
27 February 2012 (27.02.2012)	06 MAR 2012

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