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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 April 2013 (25.04.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/059201 A1

(51) International Patent Classification:
F24H 1/10 (2006.01)

(21) International Application Number:
PCT/US2012/060434

(22) International Filing Date:
16 October 2012 (16.10.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/274,930 17 October 2011 (17.10.2011) 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, BN, 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, PA, 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.

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(54) Title: TANKLESS WATER HEATER

(57) Abstract: A water heater (10) is suitable for point-of-use applications. The water heater includes a tank housing (12) and one or more electrically powered heating elements (18). A water inlet line (20) and a water outlet line (24) may be molded as a unitary structure with the tank housing. The water outlet line includes a lower port (68) and an upper port (70) for mixing water in the outlet line. The housing may be mounted such that its axis is either vertical or horizontal.

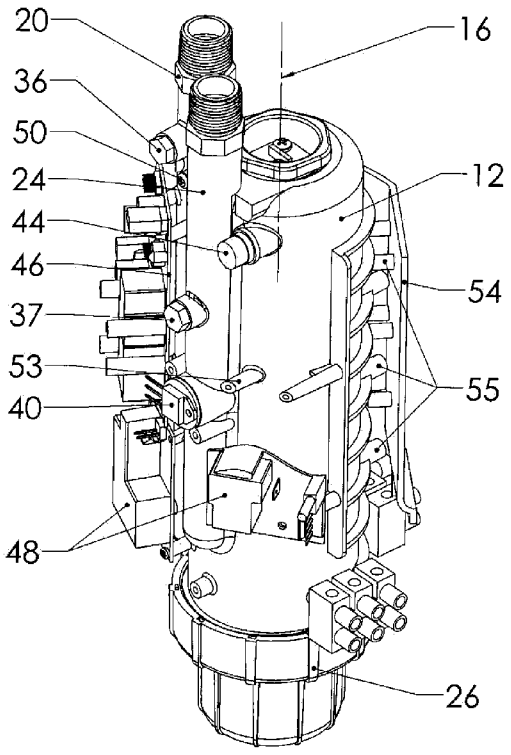


FIGURE 1

WO 2013/059201 A1

(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, 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))*

TANKLESS WATER HEATER

FIELD OF THE INVENTION

The present invention relates to water heaters, and more particularly to a "tankless" water heater with an electrically powered heating element and a relatively small tank for substantially instantaneous heating of the water.

BACKGROUND OF THE INVENTION

Various types of tankless water heaters have been devised over the years, including water heaters with electrically powered heating elements in a plastic housing. Tankless water heaters have frequently been directed to point of use, meaning the water heater was placed immediately upstream from a heated water use device, such as a sink or a shower.

Several tankless water heater manufacturers provide multiple water housings, which may be plumbed in parallel and/or in series. Another manufacturer employs a single metal tank for receiving the electrically powered heater. The water inlet to the one or more housings and the water outlet from the one or more housings typically have reduced diameters of 3/8 inch tubing. This restricted tubing in part tends to create a high fluid velocity in portions of the tank to entrain air bubbles in the fluid passing to the outlet, thereby attempting to avoid undesirable air pockets within the housing chamber. Moreover, restricted inlets and outlets create a high pressure drop such that the unit may not be suitable for various applications. Water outlets from many heaters extend from the bottom of the tank housing.

Prior art tankless water heaters have disadvantages in that the mounting orientation of the water heater is limited; most heaters must be mounted with the central tank axis vertical. Many prior tankless art water heaters subject the user to a scalding condition when latent heat after shut-down creates water hotter than desired remains in the housing chamber after the heater is shut off. After shut off, water temperature continues to increase in the housing due to the heated surroundings and the still hot heating element, and overheated hot water is subsequently released when the same or another user turns the water back on. Other tankless water heaters contain very little water, and the second user of the water does not benefit from the stored quantity of water in the heater after the first user is completed. Still other tankless water heaters use expensive flow control sensors or do not accurately detect a "flow" condition, thereby minimizing the effective control of heat to the water. Some tankless water heaters incorporate mixing valves to mix hot water discharged from the heater, thereby creating another expense to the user.

Prior art patents include U.S. Patents 5,216,743, 7,616,873, 5,866,880, 6,080,971, and 6,246,831. U.S. Patents 5,216,743, 5,866,880, 6,080,971, 6,246,831, and 7,616,873 disclose tankless water heaters with a plastic housing and improved heater controls. U.S. Patents 6,909,843, 7,567,751 and 7,779,790 disclose a single chamber heater with one or more heating elements therein.

The disadvantages of the prior art are overcome by the present invention, an improved tankless water heater is hereinafter disclosed.

SUMMARY OF THE INVENTION

In one embodiment, the water heater includes a generally cylindrical tank housing having an internal diameter and a central tank axis. One or more electrically powered heating elements are positioned within the interior chamber for heating water. A water inlet line extends from outside the tank housing to an elongate inlet port in the tank housing, and a water outlet line extends from two or more outlet ports, with a first outlet port in an upper portion of the tank and a second port spaced below the first outlet port. A flow diverter within the interior chamber is in fluid communication with the second outlet port, particularly when the tank axis is horizontal. The flow diverter inlet is below the first outlet port, so that warm water from the second outlet port mixes with hotter water from the elevated first outlet port.

These and further features and advantages of the present invention will become apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an isometric view of a tankless water heater.

Figure 2 is an exploded view of the heater shown in Figure 1.

Figure 3 is a side view of the heater shown in Figure 1.

Figure 4 is a cross-sectional view of the heater shown in Figure 3.

Figure 5 is another side view of the heater shown in Figure 1.

Figure 6 is another cross-sectional view of the heater shown in Figure 5.

Figure 7 is a side view of a suitable diverter.

Figure 8 is a cross-sectional view of the diverter shown in Figure 7.

Figure 9 is another cross-sectional view of the diverter shown in Figure 7.

Figure 10 is an isometric view of the heater housing.

Figure 11 is a top view of the heater shown in Figure 1.

Figure 12 is a bottom view of the heater shown in Figure 1.

Figure 13 is an isometric view of the diverter shown in Figure 7.

Figure 14 is an enlarged view of the upper portion of the housing shown in Figure 6.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

One embodiment of the tankless water heater 10 as shown in Figure 1 includes a generally cylindrical tank housing 12 having an internal chamber therein and a central tank axis 16. As disclosed subsequently, one or more electrically powered heating elements are provided within the internal chamber for heating water. The water inlet line 24 extends from outside the tank housing 12 to an inlet port in the tank housing, while a water outlet line 20 extends from two spaced outlet ports in the tank housing. Various mounting bosses 53 for the printed circuit board may be provided exterior of the tank housing for mounting electrical circuits and other components, such as electrical controller 46. The cover mounting bosses 55 extend radially outward from the lower part of the housing 12 and preferably are unitary with the housing, as shown in Figure 4. Mounting board 54 is also shown supported on cover mounting bosses 55. Base cap 26 is shown at the lower end of the heater in Figure 1.

Referring now to Figure 2, a base cap 26 has internal threads for mating with external threads 28 on the tank housing, with an o-ring 30 sealing between cap 26 and housing 12. A diverter 60 is positioned within the internal chamber in the tank housing and is discussed further below.

The heater includes one or more electrically powered heating elements 18 for heating water within the internal chamber 14 (see Figure 4) in the housing 12. The chamber 14 is preferably generally cylindrical, with a chamber axis aligned with the central tank axis 16, as shown in Figure 1. Electrical power to the heating element 18 as shown in Figure 2 is provided through terminals on the

head 19 of the heating element. The heating element may be supported by ring cap or gland 34, which may be threaded to the top of the tank housing. Other components of the water heater as shown in Figure 2 include inlet thermistor 37 and outlet thermistor 36, a heat sink plug 38, triac 40, terminal block 33 attached to one or more bosses, high limit temperature switch 44, PCB logic board 46, and relay 48. A water level detect screw 50 may be used to detect the fluid level (presence or absence of fluid at that level) near the top of the chamber. Signals from this sensor are input to the controller for the purpose of detecting and verifying fluid levels. Fluid flows past the heat sink to cool the control switches which are activated when heat is required. Suitable seals may be provided for sealing components with the housing sidewall.

Figure 3 is a side view of the assembly shown in Figure 2. Figures 3 and 4 illustrate the base cap 26, which has a lowermost surface 27 (see Figure 4) appreciably below the bottom of the housing 12, thereby allowing the heating element 18, if desired, to extend below the housing 12 and into the lowermost axially extending cavity provided in the base cap 27. A standard base cap with a lower surface substantially at the level of a lower end of the housing may thus be used if the heating element 18 is shorter than as shown in Figure 4, and a cap 26 with a deeper cavity may be used for receiving a heating element longer than shown in Figure 4, while continually maintaining the overall structure of the housing 12 and components attached thereto. Figure 3 illustrates that the inlet threaded nipple 21 to line 24 and outlet threaded nipple 25 from line 20 are each at a level substantially above the upper end of the housing 12 when mounted

with its axis vertical, thereby reducing the likelihood of a connection leak compared, for example, to a flow line which is threadably connected directly to the housing 12. Each of fluid inlet line 24 and fluid outlet line 20 have an interior diameter preferably greater than 0.6 inches. Lines 20 and 24 have a respective inlet and outlet spaced at least 50% of the diameter of internal chamber 14 from any portion of the tank housing. The cylindrical tank housing has an interior chamber diameter greater than 2.0 inches. Figure 4 also depicts the triac 40 shown in Figure 2, and thermistor 36 and inlet line 20.

Figure 4 discloses the fluid inlet line 20 having an elongate fluid disbursement slot 58 which provides communication between the inlet line and the interior of the chamber. Desirably, the incoming water is input to the interior chamber along an axial path of fluid disbursement slot 58 which is in excess of 40% of the axial length of the interior chamber, thereby contributing to both good mixing of the incoming water and any heated water already in the chamber, and even heating along the axis of the heating element to which the fluid is directed. The elongate fluid disbursement slot 58 allows the inlet water to be evenly dispersed over the top of the heater and will be rapidly preheated by water previously heated by the last user and retained in the upper portion of the chamber, thereby using this hot water (hot spot water) not only to preheat the incoming water, but also to cool the hot spot water to assist in preventing scalding water. The fluid disbursement slot 58 distributes water to both the upper portion and the lower portion of the internal chamber 14. The elongate fluid disbursement slot 58 also preferably distributes water along a majority of the

axial length of the heating element for better distribution of heat transfer to fluid within the chamber.

Figure 5 shows the same heater with fluid inlet line 24 and fluid outlet line 20 each integral with the housing 12. Figure 6 is a cross-section through the fluid outlet line and the internal chamber 14 within the heater housing 12, and illustrates diverter 60. The diverter 60 diverts and controls the percent of cooler fluid introduced from the lower outlet and thus the lower portion of the chamber with the hotter fluid from the upper outlet and thus the upper portion of the chamber, such that the resulting outlet water will not exceed minimum scalding temperature. The diverter 60 controls the entry of fluid into a lower end of the outlet line 20. The upper aperture 70, as shown in Figure 14, draws hotter fluid from the upper portion of the chamber to pass directly into the outlet line 20 for mixing with the cooler fluid drawn the lower portion of the chamber.

Vent hole 90 vents noncondensible gas/air from the internal chamber 14 to the outlet line 20. Only a small vent hole having an exemplary diameter of 3/16 inch or less is required to reliably vent noncombustible gas/air from the chamber to the discharge or outlet line 20. Changing the size of the upper outlet aperture 70 controls the ratio of the mixing of warm water from the diverter with hotter water from the aperture 70. A smaller aperture 70 thus provides a greater degree of protection against scalding. The size of the aperture 70 may thus depend upon the application and the need to minimize scalding for that application.

Figure 7 is a side view of a suitable diverter 60, which serves as a fluid outlet and controls the volume of water from the lower outlet aperture and thus the lower portion of the outlet line. The diverter thus diverts and controls the volume of cooler water introduced from the lower portion of the chamber through the diverter 60, which has a vertical cross-section body 71 as shown in Figure 9 and a horizontal cross-section 62 as shown in Figure 8. The diverter's horizontal cross-section includes entry port 65 which delivers fluid to a curved flow path 63, which connects at diverter outlet to chamber 66, which in turn is in fluid communication with the lower outlet aperture 68 (see Figure 6) in the housing and thus the interior of the outlet line 20. The diverter 60 thus sits against the curved inner sidewall of the housing, and diverts fluid from either above and/or below the diverter and adjacent the housing interior sidewall into the outlet line 20, with the lower outlet aperture 68 being in a lower portion of the chamber when the housing axis 16 is vertical. When the axis of the housing is horizontal, which is an alternative mounting technique, the diverter 60 as shown in Figures 7-9 takes water from a lower or midsection portion of the chamber (which is inherently cooler than water in the uppermost part of the chamber), and similarly diverts that water through the channel 63 into the outlet line 20. Since hot water in a chamber rises and cold water sinks, "hot spots" of elevated temperature water from the hot heater element (even when turned off) rise to the top of the chamber. A pictorial view of the diverter 60 is shown in Figure 13.

As briefly discussed above, the heater may be vertically mounted so that the central housing axis 16 is substantially vertical, or may be horizontally

mounted so that the central housing axis 16 is substantially horizontal. For the vertical mounting application, water passes from the inlet line through the fluid disbursement slot 58, which is preferably is a substantially vertical slot, and thus inputs cold water along a substantial length of the inner chamber in the housing and thus directed across a substantial portion of the length of the heating element. Lower outlet aperture 68, as shown in Figure 6, is in a lower portion of the housing, and thus draws water from the lower portion of the chamber. Water passing from the chamber through the lower outlet aperture 68 is thus typically cooler, and may be appreciably cooler, than water in the upper portion of the chamber due to convection and stratification of the hotter water. This is particularly true at heater start up after a previous use. Water from the lower outlet aperture 68 thus mixes in the outlet line 20 with hotter water from the upper outlet aperture 70, and this mixing desirably reduces scalding, particularly under circumstances where water is passing through the heater when the user shuts off the water. Upper outlet 70 normally has a smaller cross-sectional area than lower outlet 68. Because of latent heat in the heating element, scalding is particularly problematic in the use of a tankless water heater due to the relatively high wattage elements compared to low volume of total fluid in the heater, which has a tendency to raise the temperature in an upper part of the chamber (whether vertically or horizontally mounted) above the desired set point, while the water in a lower portion of the heater is lowering in temperature as the temperature stratifies in the chamber. Most water heaters draw water from the hottest portion of the chamber, and when the same or another user turns on the

water, the user may be scalded. By drawing at least some portion of the water from the lower end of the chamber, the likelihood of scalding is substantially reduced. Positioning the upper hole 70 within 20% of the uppermost part of the chamber, and positioning the lower hole 68 within 20% of the lowermost part of the chamber enhances the repeatability of water at a desired temperature exiting the unit, compared, for example, to hole 70 being above but spaced within 2 inches of hole 68.

For a horizontal mounting application, water in the inlet line passes through the fluid disbursement slot 58, which in this case is a substantially horizontal slot, to input water along a substantial horizontal length of the chamber and heating element in the housing. Lower outlet aperture 68 as shown in Figure 6 is not in a lower portion of the housing, but the diverter 60 when used with the horizontal mount application assures that water is drawn off the lower portion of the horizontal chamber, since in the horizontal mount application, the inlet to the diverter is below the hole 68, and thus receives cooler water than water in the upper portion of the chamber. Thus water in a lower portion of the chamber is drawn and mixed with water from the upper portion of the chamber, as with the vertical mount application. Water from the upper portion of the chamber may pass through the upper outlet aperture 70 to the outlet line, and is mixed with the cooler water from the lower portion of the chamber to again prevent scalding. Although only outlet apertures 70 and 68 are shown, one or more additional outlet ports could be provided between chamber 14 and line 20.

For the horizontal mount application, the fluid inlet 58 to the chamber and the upper outlet aperture 70 from the chamber are preferably at substantially the same elevation, so that at startup of the unit, cool incoming water from fluid inlet 58 mixes with the hot water adjacent upper outlet aperture 70 to minimize scalding. Each of the fluid disbursement slot 58 and the water upper outlet aperture 70 are preferably provided within at least the upper third of the horizontally mounted chamber, while the lower outlet aperture 68 is in the lower portion of the chamber. Preferably the fluid disbursement slot 58 and the upper outlet aperture 70 are at substantially the same elevation, and in most applications the difference in their elevations will vary by less than 1/2 inch. Each of the inlet line 24 and the outlet line 20 are preferably spaced in a 90° quadrant at the upper end of the horizontally mounted cylindrical housing. Effective control of the water temperature discharged from the unit is thus enhanced by mixing hot water in the upper portion of the chamber with cool water from the lower portion of the chamber.

The size of the flow through aperture in the diverter 60 and the size of the upper outlet aperture 70 may be selected to maximize the performance of the heater for each application. For example, the time to reach set point vs. scald potential may be balanced for the application. The heater allows one to easily accomplish this balance without a secondary mixing device. Once the heater has been used, there is storage of preheated water that allows the second user to instantaneously draw hot water within a period of an hour or longer.

The vent hole 90 as shown in Figure 14 functions as a vent hole to vent gas from the chamber to the outlet line 20 when the tank central axis is either vertical or horizontal. The vent hole 90 is thus desirably located so that when mounted vertically or horizontally, the hole is at the uppermost portion of the chamber. When the heater is horizontally mounted, the first aperture 70 is circumferentially positioned so that it draws water from the upper portion of the chamber and vents gas from the upper portion of the chamber, while the deflector 60 draws water from a lower portion of the chamber. When horizontally mounted, the inlet line 24 and the outlet line 20 are preferably within a horizontal plane (the axes of the two lines are in a single horizontal plane), which allows mixing of the incoming water and water output through the upper output aperture 70. Lines 20 and 24 are also preferably spaced circumferentially within a quadrant of the tank housing so that both lines are in communication with an upper portion of chamber 19, whether vertically or horizontally mounted.

Figure 10 is a pictorial view of the housing 12 as well as the components which are integral with and homogeneous with the housing 12, including the inlet line 24, the outlet line 20, and mounting bosses 55 (see Figure 1) for supporting wall mounting plate 54. By providing inlet and outlet lines which are integral with the housing, the number of leak paths to and from the heater are significantly reduced, and as previously noted the interconnection of a flow line to each of the inlet and outlet lines may desirably be made at a location spaced from the housing 12. The integral housing 12, inlet line 24, and outlet line 20 also provide strength and a significantly reduced likelihood of cracking or otherwise damaging

components during the installation or repair of the heater, since the structural integrity of the combined housing and flow lines substantially reduces the likelihood of breaking one of the lines or its connection to the housing.

Figure 11 is a top view of the heater as shown in Figure 1, with the heating element ring cap or gland 34 positioned within the interior of the ring cap 34. Figure 12 is a bottom view of the same heater, showing the base cap 26 and various electrical components supported on the housing 12.

Figure 14 is an enlargement of the upper portion of the housing shown in Figure 6, and illustrates the upper outlet aperture 70 between the internal chamber 14 and the water outlet line 20. The upper outlet aperture 70 is provided in an uppermost portion of the chamber to release gases in the upper portion of the chamber, and also for passing heated fluid from the top of the chamber to the outlet line 20 to mix with the fluid from the lower hole in the outlet line which receives fluid from the diverter 60. A small amount of fluid from the inlet line 24 flows through the fluid disbursement slot 58 and directly into the upper portion of the chamber to mix with other fluid in the upper portion of the chamber and thereby prevent fluid in the chamber from overheating while water is flowing through the heater. Vent hole 90 as shown in Figure 14 optionally may be provided between the upper portion of the chamber to vent gas to the water outlet line 20.

Figure 14 also illustrates the threaded connection between the element ring cap 34 and the housing 12. Tightening the element ring cap 34 thus presses down on the flange of the head 19, thereby compressing the element

seal 80. By providing the fluid tight element seal 80 between the chamber 14 and the element ring cap 34, threads 82 between the cap and the housing are protected from engagement with the fluid in the chamber and thus the chemical attack of hot fluid on the threads, thereby contributing to reliable sealing which is not obtained if the cap threads and the housing threads are exposed to the heated fluid.

A feature of the invention is the technique by which the controller determines that a "flow" condition exists, i.e., fluid is passing through the housing, which determination affects the operability of the heater. More particularly, the prior art heaters determined a flow versus a no flow condition based upon expensive detectors which respond directly to the flow of water, or based upon temperature sensors alone which in use do not reliably provide an indication of flow. According to the present invention, a flow determination is made by the controller based on an inlet temperature signal from sensor 85 (shown in Figure 6) and an outlet temperature signal from sensor 87. More particularly, the controller 48 determines a flow condition based upon an absolute value of the change in the absolute value of the temperature sensed upstream from the inlet port, i.e., by thermistor 37 (see Figure 2), and the change in the absolute value of the temperature sensed by thermistor 36 downstream from the upper outlet aperture 70. Applicant has discovered that the sum of the absolute value of the combined temperature change from these two sensors provides an accurate and substantially immediate determination of a flow condition, which may reliably be used by the controller, e.g., controller 48, to

control power to the heating elements. Under normal "no flow" conditions, the change in temperature from the inlet temperature sensor and the outlet temperature sensor will be less than a selected reference temperature, so that the heater stays in the "stand-by" condition. When fluid flow starts, the controller 48 determines flow, typically within a few seconds, e.g., less than two seconds, based upon the absolute value of the change in the inlet temperature plus the change in absolute value of the outlet temperature, with the sum compared to a delta reference temperature. Flow may thus be determined without any mechanical flow detection means and without supplying any stand-by heating to the chamber to maintain the temperature difference between the inlet temperature and the outlet temperature.

The present heater may be used for point-of-use applications, meaning that the heater is installed closely adjacent, e.g., within ten feet, of the use. For a public laboratory application, the heater may be provided directly under each sink, or one heater may supply hot water to two or more sinks. For these applications, the size of the chamber which holds water is important, and for that size chamber there is a preferred power range for the heating element. More particularly, Applicant has determined that an instantaneous or "tankless" water heater preferably has an internal housing chamber of from 20 ounces to 80 ounces, with one or more electrically powered heaters in the chamber having combined power from 2 kilowatts to 10 kilowatts. The heater may also be used for "heat and boost" applications, wherein the heater as disclosed herein is provided with a preheated fluid and "boosts" the fluid temperature for a specific

use. The heater may also be used for stand alone or a "whole house" heating application.

While the heater as disclosed herein is particularly well-suited for heating water, the heater may be used for heating other liquids, such as cleaning solutions. While the heater is particularly well-suited for heating liquid with one or more electrically powered heating elements, various concepts of the invention, including the use of spaced holes which combine in the fluid outlet to mix colder fluid with fluid, may be used for an instantaneous gas heater application.

Although specific embodiments of the invention have been described herein in some detail, this has been done solely for the purposes of explaining the various aspects of the invention, and is not intended to limit the scope of the invention as defined in the claims which follow. Those skilled in the art will understand that the embodiment shown and described is exemplary, and various other substitutions, alterations and modifications, including but not limited to those design alternatives specifically discussed herein, may be made in the practice of the invention without departing from its scope.

WHAT IS CLAIMED IS:

1. A water heater, comprising:

a tank housing having an internal chamber and a central tank axis;

one or more electrically powered heating elements for heating water within the internal chamber;

a water inlet line extending from outside the tank housing through an inlet port in an upper portion of the tank housing; and

a water outlet line extending from two or more outlet ports from the tank housing, a first outlet port being in the upper portion of the tank housing, and a second outlet port being spaced below the first outlet port.

2. A water heater as defined in Claim 1, wherein the central tank axis is substantially vertical, and the second outlet port is in a lower portion of the tank housing.

3. A water heater as defined in Claim 1, wherein the central tank axis is substantially horizontal, the inlet port and first outlet port are each in the upper portion of the tank, and a diverter diverts fluid from a lower portion of the internal chamber to the second outlet port.

4. A water heater as defined in Claim 1, further comprising:

the one or more electrically powered heating elements engaging an end of the tank housing; and

a cap removably secured to the tank housing for access to the internal chamber at a location axially opposite the engagement of the one or more electrically powered heating elements and the end of the tank housing, the cap having an axially extending cavity therein to receive an unsupported end of the one or more electrically powered heating elements.

5. A water heater as defined in Claim 1, further comprising:

a controller for controlling power to the one or more heating elements, the controller responsive to a "flow" condition based on an absolute value of the change in temperature sensed upstream from the inlet port and the absolute value of the change in the temperature sensed downstream from the first outlet port.

6. A water heater as defined in Claim 1, further comprising:

an inlet temperature sensor for sensing water temperature in the water inlet line;

an outlet temperature sensor for sensing water temperature in the water outlet line; and

a controller responsive to the inlet temperature sensor and the outlet temperature sensor for controlling power to the one or more electrically powered heating elements.

7. A water heater as defined in Claim 1, wherein an electrical capacity of the one or more electrically powered heaters in kilowatts is from 2 kW to 10 kW, and the volume of the internal chamber containing the heater is from 20 ounces to 80 ounces.

8. A water heater as defined in Claim 1, wherein a portion of the water outlet line shares a common wall with the tank housing; and

a vent hole in the housing venting air from the chamber to the water outlet line when the tank axis is substantially vertical, and venting air from the chamber to the water outlet line when the tank axis is substantially horizontal.

9. A water heater as defined in Claim 1, wherein a portion of the water inlet line shares a common wall with the tank housing.

10. A water heater as defined in Claim 1, wherein each of the water inlet line and the water outlet line are integral with the tank housing, and are spaced circumferentially within a quadrant of the tank housing.

11. A water heater as defined in Claim 1, wherein the tank housing, water inlet line, and the water outlet line are molded as a unitary and monolithic structure.

12. A water heater as defined in Claim 1, further comprising:

a diverter within the interior chamber in fluid communication with the second outlet port, the diverter extending substantially inward from the second outlet port into the internal chamber, and having an inlet opening to receive heated water from a lower portion of the internal chamber.

13. A water heater as defined in Claim 1, wherein an inlet to the water inlet line and an outlet from the water outlet line are each spaced at least 50% of a diameter of the cylindrical chamber from any portion of the tank housing.

14. A water heater as defined in Claim 1, wherein an interior diameter of each of the water inlet line and the water outlet line is greater than 0.6 inches, and the tank housing interior diameter is greater than 2.0 inches.

15. A water heater, comprising:

a tank housing having an internal chamber and a central tank axis;

one or more electrically powered heating elements for heating water within the interior chamber;

a water inlet line extending from outside the tank housing to an inlet port in a side of the tank housing;

a water outlet line extending from an outlet port in a side of the tank housing to the exterior of the tank housing; and

each of the water inlet line and the water outlet line are integral with the tank housing, and are spaced circumferentially within a quadrant of the tank housing.

16. A water heater as defined in Claim 15, further comprising:

a diverter within the internal chamber in fluid communication with the second outlet port, the diverter extending substantially inward from the second outlet port into the interior chamber, and having an inlet opening to receive heated water from a lower first portion of the chamber, and from a generally axially centered second portion of the chamber when the tank axis is substantially horizontal.

17. A water heater as defined in Claim 15, wherein the tank housing, water inlet line, and the water outlet line are molded as a unitary and monolithic structure.

18. A water heater as defined in Claim 15, wherein the one or more electrically powered heating elements engage an end of the tank housing; and

a cap removably secured to the tank housing for access to the internal chamber at a location axially opposite the engagement of the one or more electrically powered heating elements and the tank housing, the cap removably secured to the tank housing for access to the internal chamber at a location axially opposite the engagement of the one or more electrically powered heating

elements and the end of the tank housing, the cap having an axially extending cavity therein to receive an unsupported end of the one or more electrically powered heating elements.

19. A water heater as defined in Claim 15, wherein an interior diameter of each of the water inlet line and the water outlet line is greater than 0.6 inches, and the tank housing interior diameter is greater than 2.0 inches.

20. A method of heating, comprising:

providing a tank housing having an internal chamber and a central tank axis;

providing a water inlet line extending from outside the tank housing to an inlet port in a side of the tank housing;

providing a water outlet line extending from the tank housing to the exterior of the tank housing, the water outlet line having two or more ports in the tank, a first outlet port being in the upper portion of the tank, and a second outlet port being spaced substantially below the first outlet port; and

providing one or more electrical heating elements for heating water within the interior chamber.

21. A method as defined in Claim 20, further comprising:

providing a diverter within the interior chamber in fluid communication with the outlet port, the diverter extending substantially inward from the outlet port into

the interior chamber, and having an inlet opening to receive heated water from a lower first portion of the chamber when the tank axis is substantially vertical, and from a generally axially centered second portion of the chamber.

22. A method as defined in Claim 20, further comprising:

providing an electrical capacity of the one or more electrically powered heaters in kW is from 2 kW to 10 kW, and the volume of the internal chamber containing the heater is from 20 ounces to 80 ounces.

23. A method as defined in Claim 20, further comprising:

sensing the temperature of water in the water inlet line;

sensing the temperature of water in the water outlet line; and

providing a controller responsive to the sensed inlet temperature and the sensed outlet temperature for controlling power to one or powered heating elements.

24. A method as defined in Claim 20, wherein a portion of the water outlet line shares a common wall with the tank housing; and

venting air from the chamber through a vent port to the water outlet line when the tank axis is substantially vertical, and venting air from the chamber through the vent port to the outer outlet line when the tank axis is substantially horizontal.

25. A method as defined in Claim 20, wherein each of the water inlet line and the water outlet line are integral with the tank housing, and are spaced circumferentially within a quadrant of the tank housing.

26. A method as defined in Claim 20, further comprising:

forming the tank housing, the water inlet line, the water outlet line as a unitary and monolithic structure.

27. A method as defined in Claim 20 wherein an interior diameter of each of the water inlet line and the water outlet line is greater than 0.6 inches, and the tank housing interior diameter is greater than 2.0 inches.

28. A water heater, comprising:

a tank housing having an internal chamber and a central tank axis;

one or more electrically powered heating elements for heating water within the internal chamber;

a water inlet line extending from outside the tank housing to an inlet port;

a water outlet line extending from an outlet port in the tank; and

a controller for controlling power to the one or more heating elements, the controller responsive to a "flow" condition based on an absolute value of the change in temperature sensed upstream from the inlet port and the absolute value of the change in the temperature sensed downstream from the first outlet port.

29. A water heater as defined in Claim 28, wherein a portion of the water inlet line shares a common wall with the tank housing.

30. A water heater as defined in Claim 28, wherein each of the water inlet line and the water outlet line are integral with the tank housing, and are spaced circumferentially within a quadrant of the tank housing.

31. A water heater as defined in Claim 28, wherein the one or more electrically powered heating elements engage to an end of the tank housing; and

a cap removably secured to the tank housing for access to the internal chamber at a location axially opposite the engagement of the one or more electrically powered heating elements and the end of the tank housing.

32. A water heater as defined in Claim 28, further comprising:

a diverter within the interior chamber in fluid communication with the second outlet port, the diverter extending substantially inward from the second outlet port into the internal chamber, and having an inlet opening to receive heated water from a central portion of the internal chamber.

33. A water heater, comprising:

a generally cylindrical tank housing having an internal chamber and a central tank axis;

one or more electrically powered heating elements for heating water within the internal chamber and engaging an end of the tank housing;

a water inlet line extending from outside the tank housing through an inlet port in an upper portion of the tank housing;

a water outlet line extending from an axially spaced outlet port from the tank housing;

a seal ring for sealing between the one or more heating elements and the tank housing; and

a gland threaded to the tank housing for forcing the one or more heating elements into sealing engagement with the seal thereby isolating the gland/housing threads from water in the internal chamber.

34. A water heater as defined in Claim 33, further comprising:

a cap removably secured to the tank housing for access to the internal chamber at a location axially opposite the engagement of the one or more electrically powered heating elements and the end of the tank housing.

35. A water heater as defined in Claim 33, further comprising:

an inlet temperature sensor for sensing the temperature of water in the water inlet line;

an outlet temperature sensor for sensing the temperature of water in the water outlet line; and

a controller responsive to the inlet temperature sensor and the outlet temperature sensor for controlling power to one or more electrical powered heating elements.

36. A water heater as defined in Claim 33 further comprising:

a controller for controlling power to the one or more heating elements, the controller responsive to a "flow" condition based on an absolute value of the change in temperature sensed upstream from the inlet port and the absolute value of the change in the temperature sensed downstream from the first outlet port.

37. A water heater as defined in Claim 33, wherein each of the water inlet line and the water outlet line are integral with the tank housing, and are spaced circumferentially with a quadrant of the tank housing.

38. A water heater as defined in Claim 33, wherein the tank housing, water inlet line, and the water outlet line are molded as a unitary and monolithic structure.

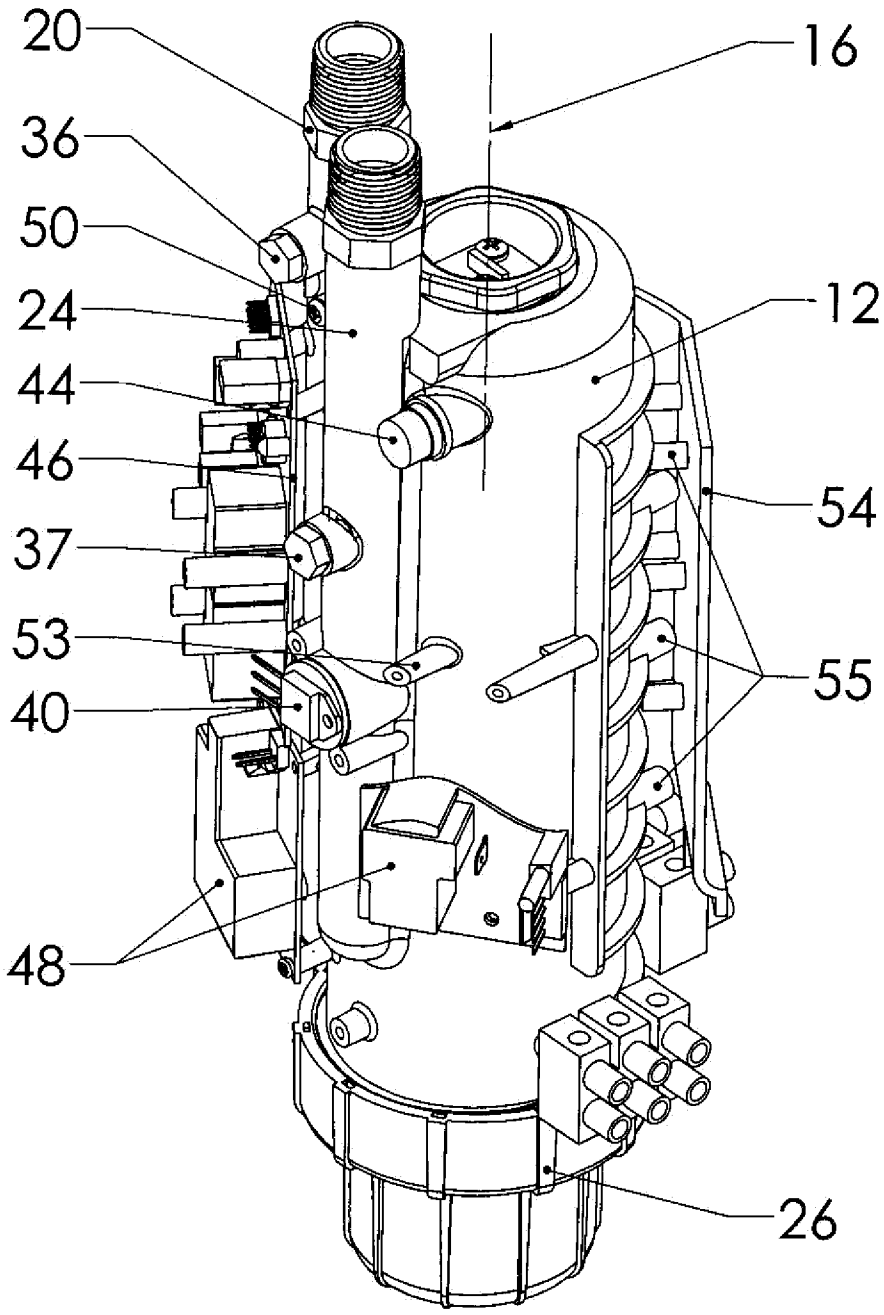


FIGURE 1

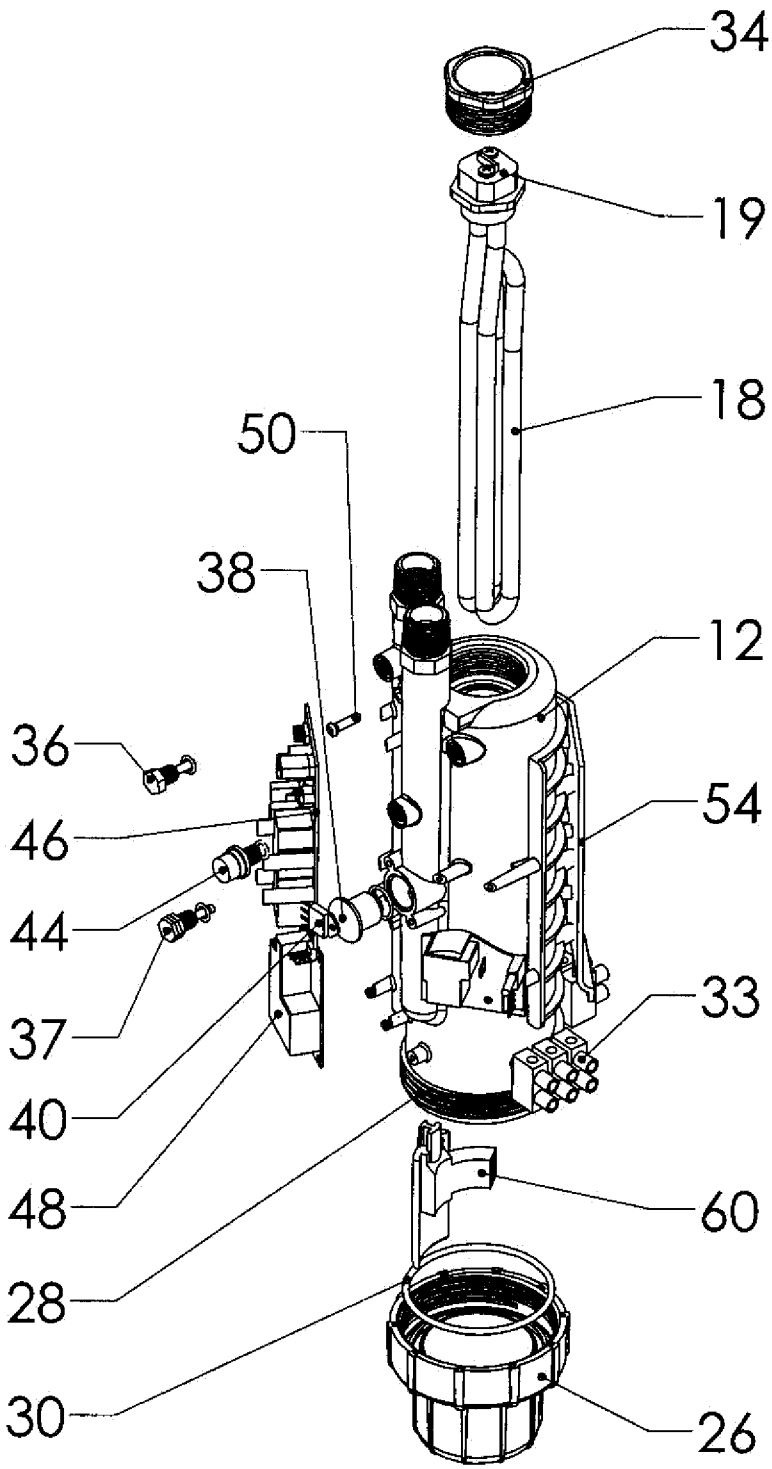


FIGURE 2

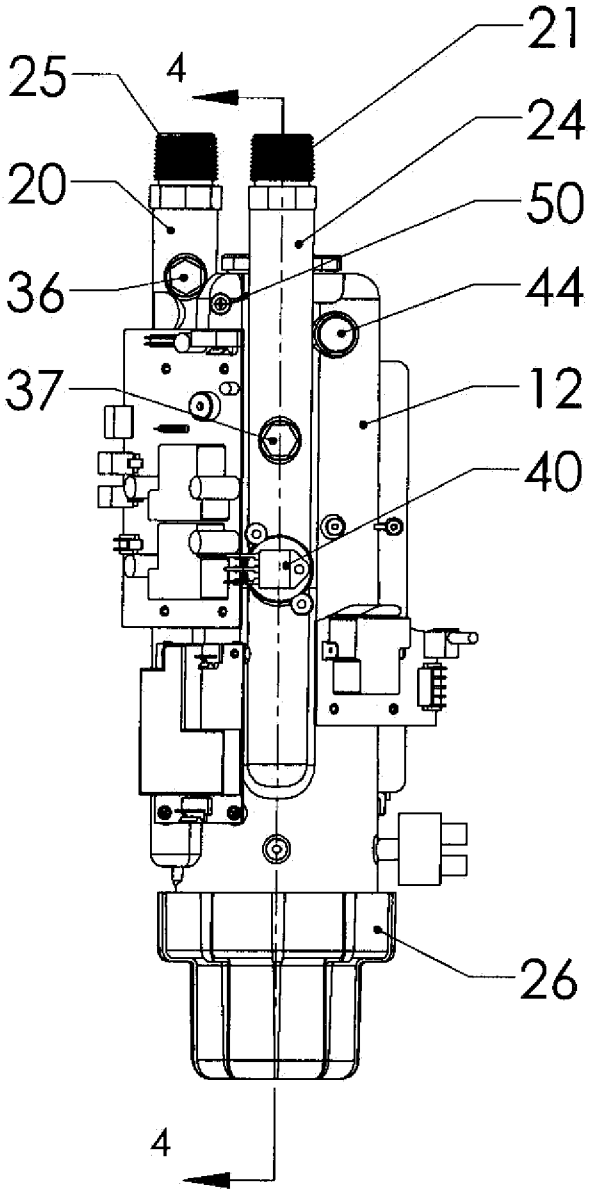


FIGURE 3

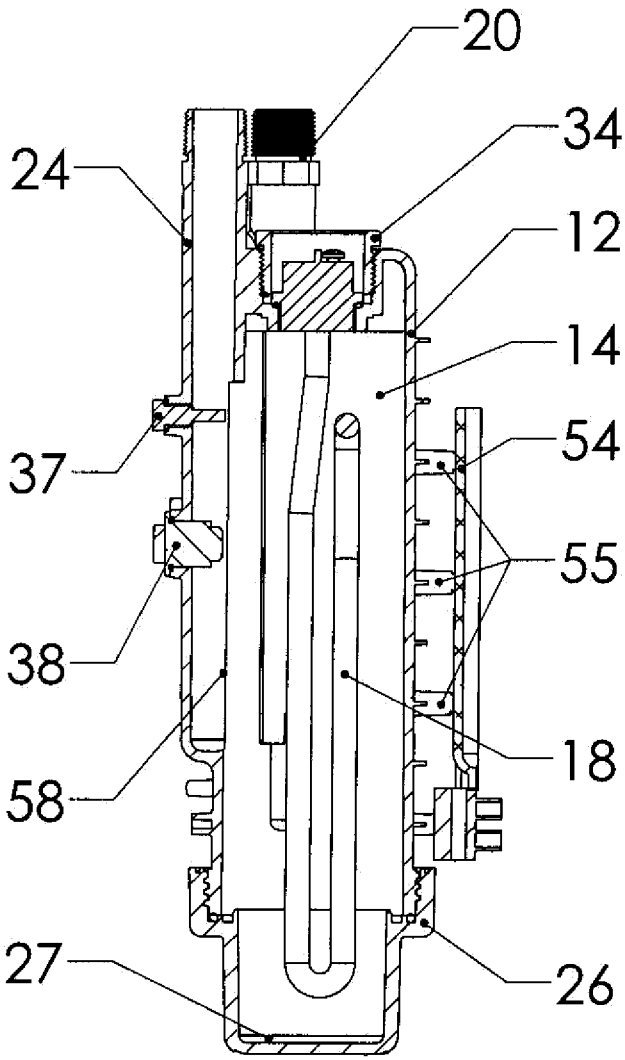


FIGURE 4

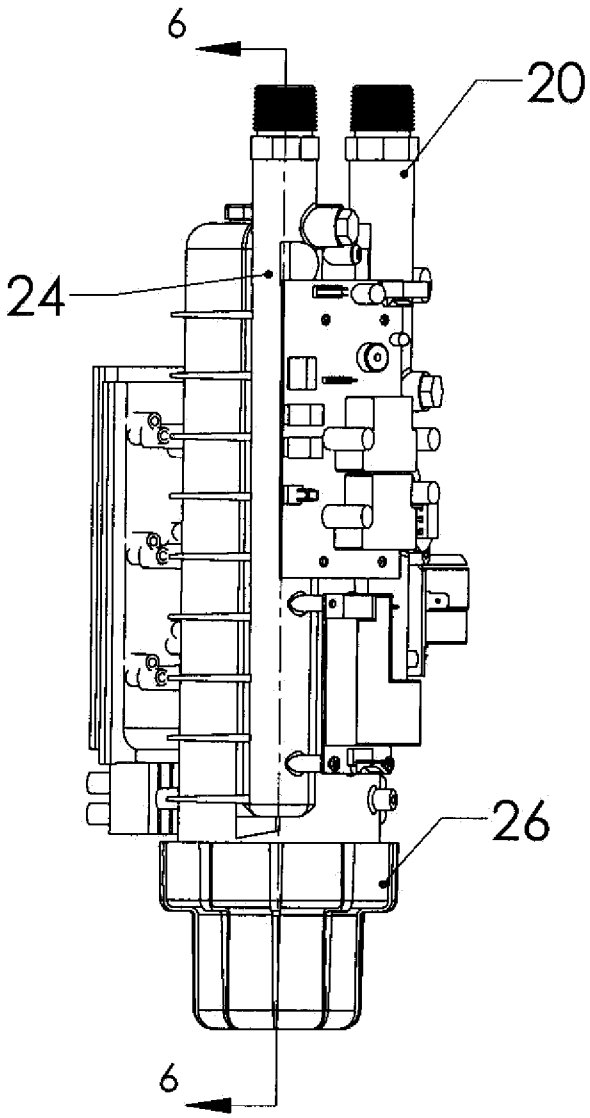


FIGURE 5

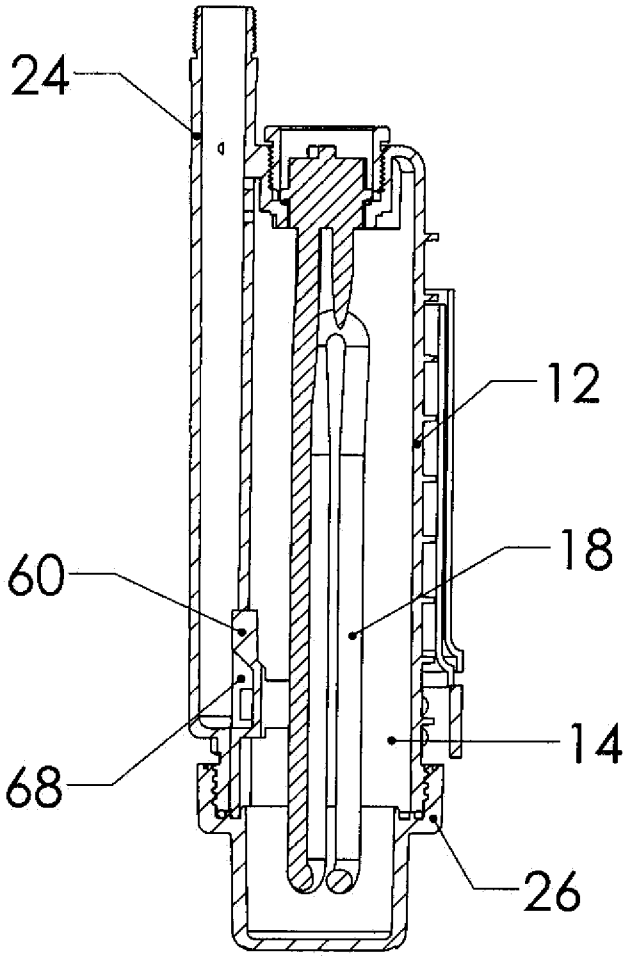


FIGURE 6

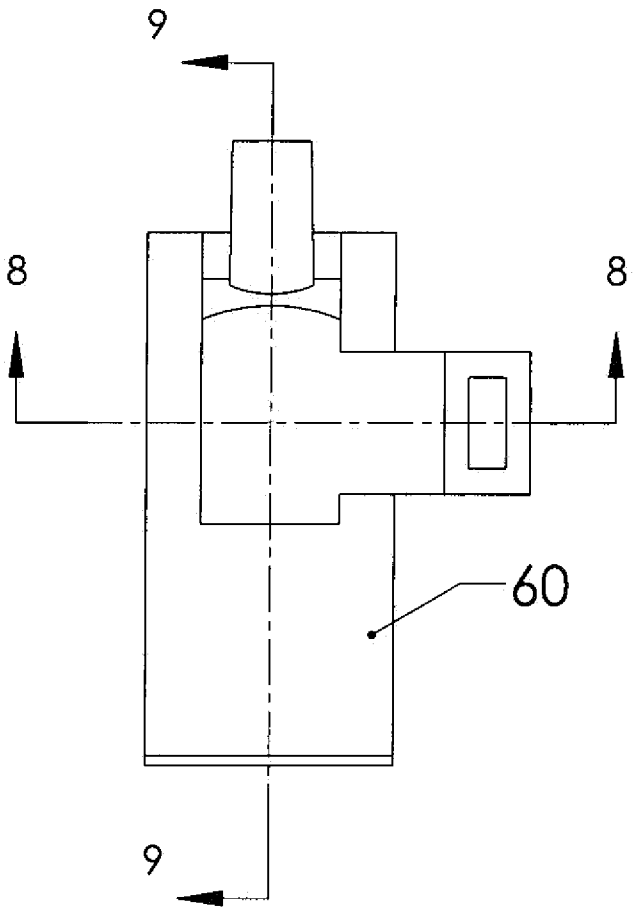


FIGURE 7

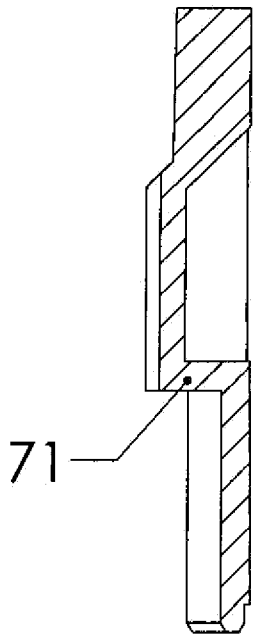


FIGURE 9

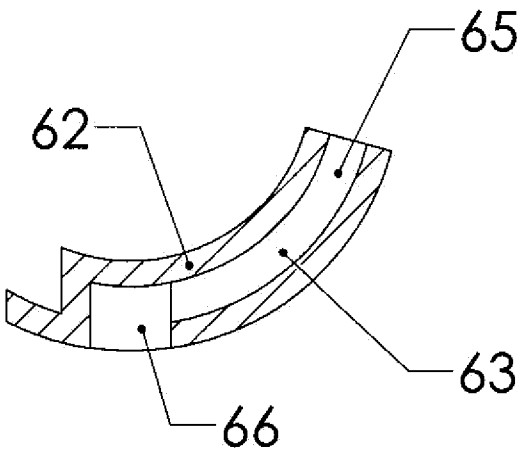


FIGURE 8

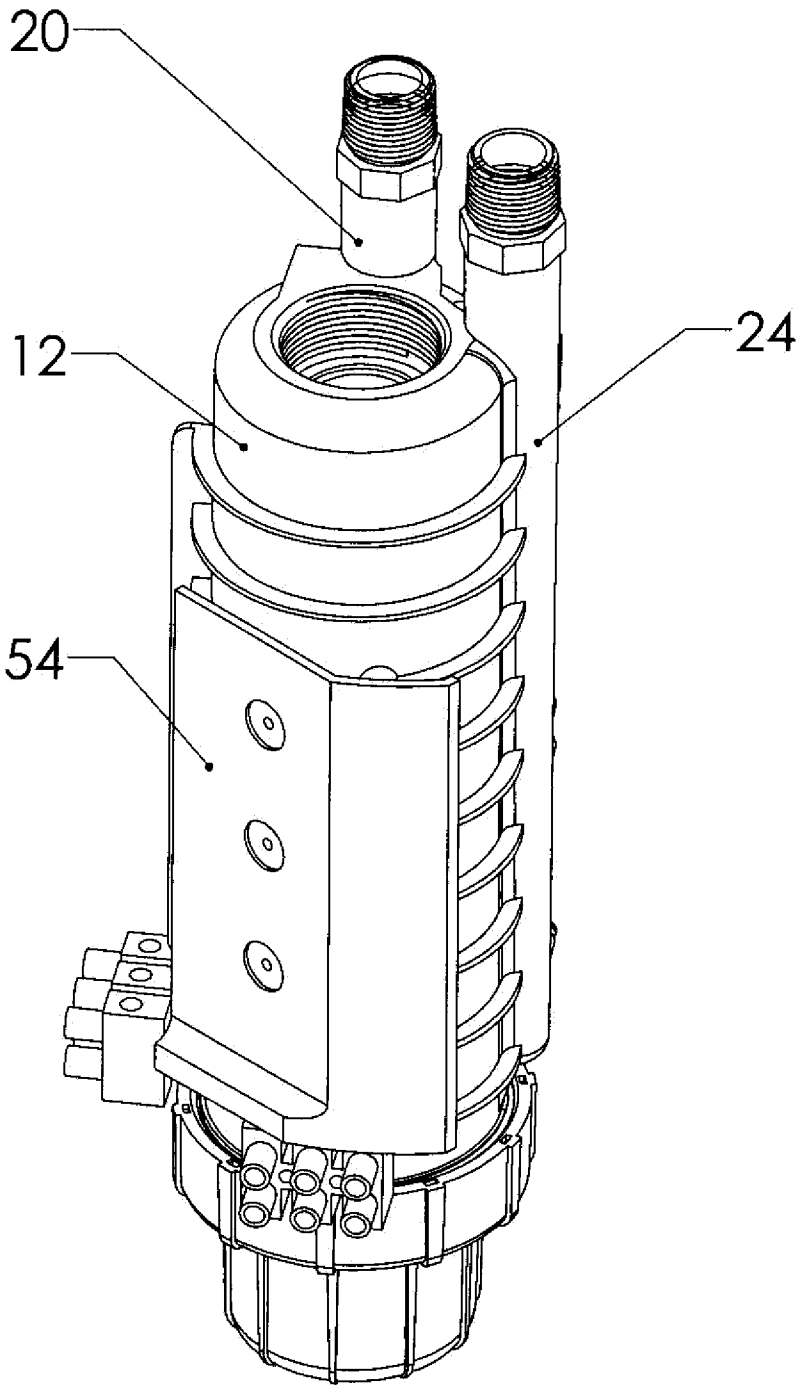


FIGURE 10

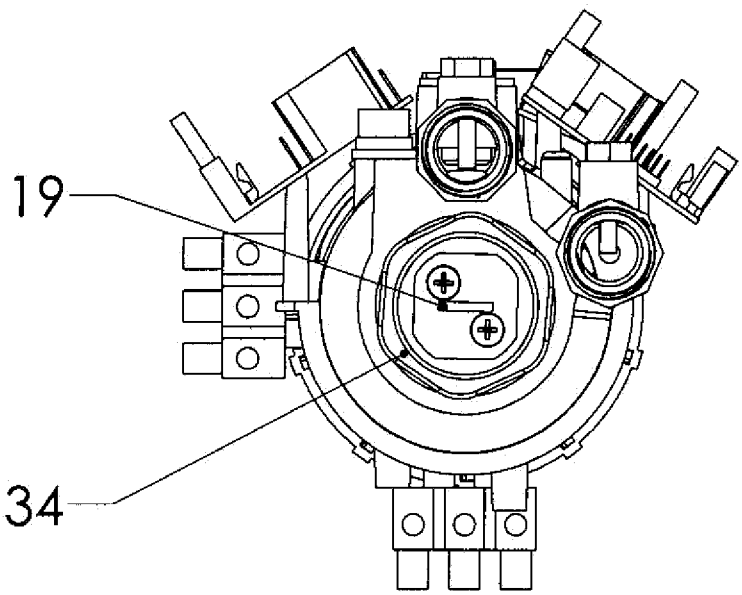


FIGURE 11

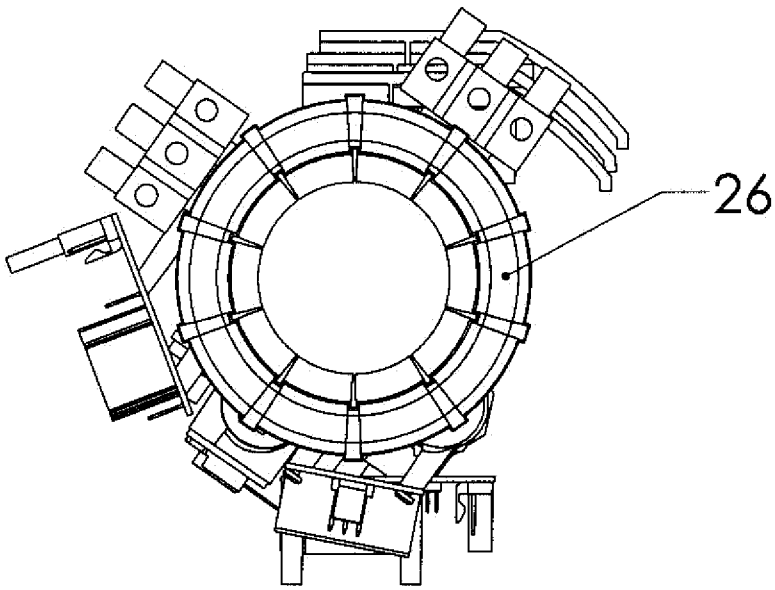


FIGURE 12

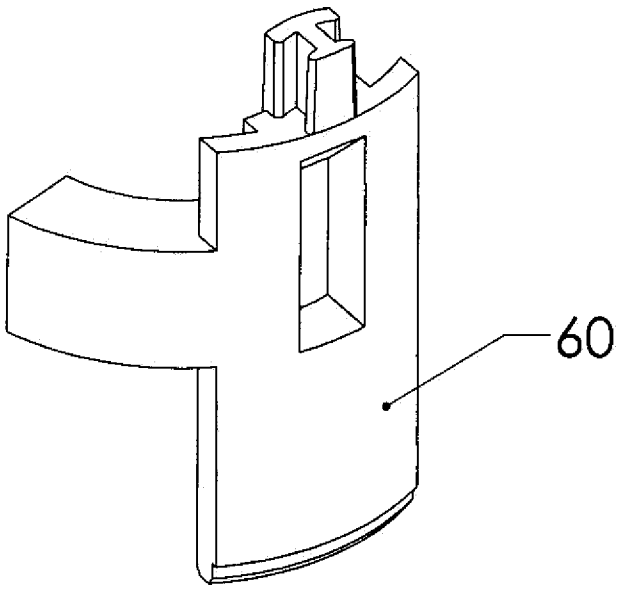


FIGURE 13

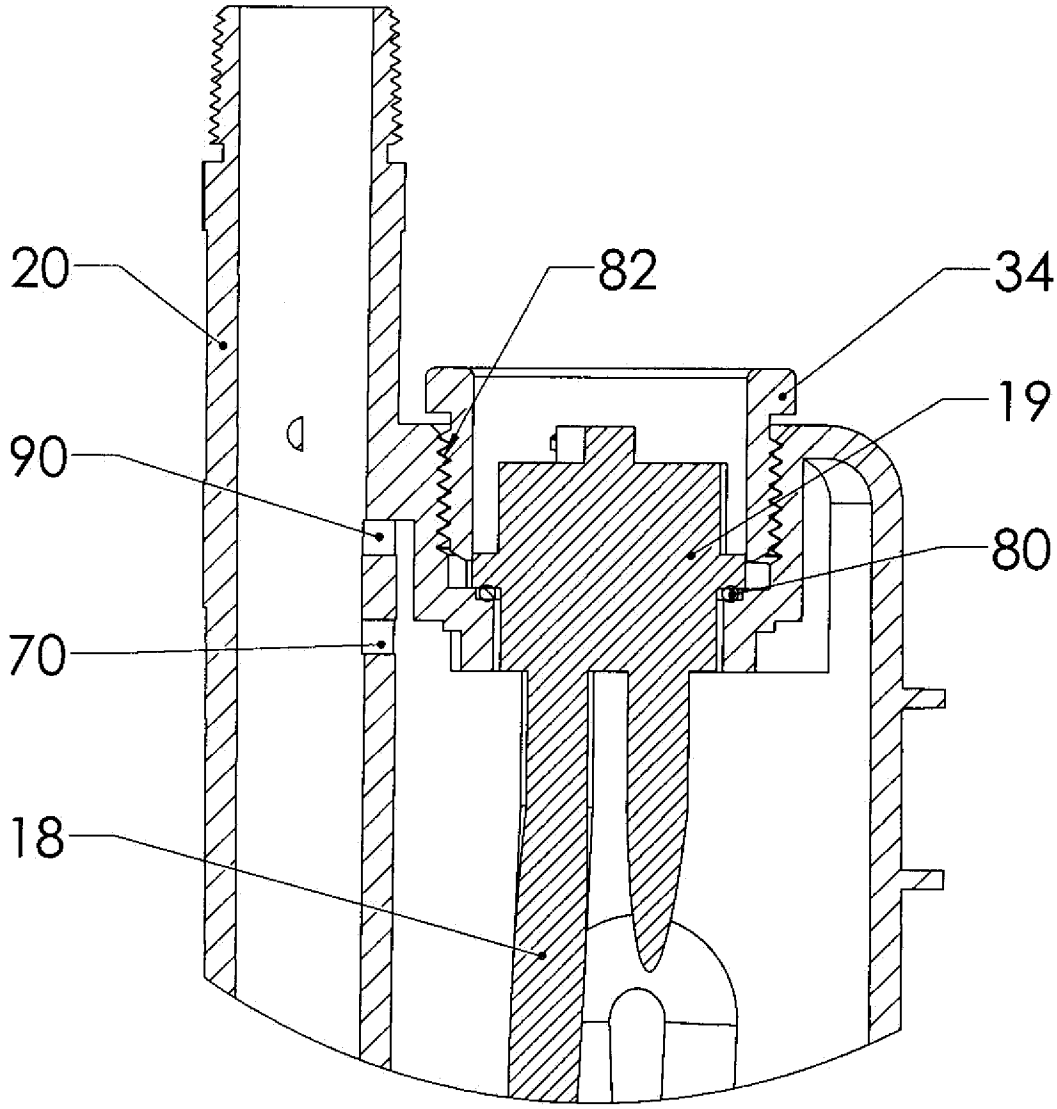


FIGURE 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/060434

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F24H 1/10 (2012.01)
USPC - 392/490
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)
IPC(8) - B60H 1/00; C02F 1/00, 1/48, 5/00; F22B 27/00; F24H 1/10, 1/14, 9/20; G05D 23/24; H05B 3/78 (2012.01)
USPC - 122/4A, 40; 219/481, 483, 494, 497, 506; 237/2A; 392/465, 474, 475, 485, 486, 488, 490, 492

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7,779,790 B2 (FABRIZIO) 24 August 2010 (24.08.2010) entire document	1, 2, 4, 7, 9, 10, 13-15, 18-20, 22, 25, 27, 33, 34, 37
Y	US 4,604,515 A (DAVIDSON) 05 August 1986 (05.08.1986) entire document	1, 2, 4, 7, 9, 10, 13-15, 18, 19, 25, 33, 34, 37
Y	CN 101398219 A (YU et al) 01 April 2009 (01.04.2009) entire document	4, 18, 33, 34, 37
Y	US 5,408,578 A (BOLIVAR) 18 April 1995 (18.04.1995) entire document	20, 22, 25, 27
A	US 7,616,873 B1 (SEITZ) 10 November 2009 (10.11.2009) entire document	1-38
A	US 5,724,478 A (THWEATT) 03 March 1998 (03.03.1998) entire document	1-38
A	US 7,945,146 B2 (CABRERA) 17 May 2011 (17.05.2011) entire document	1-38

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 December 2012	18 JAN 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)