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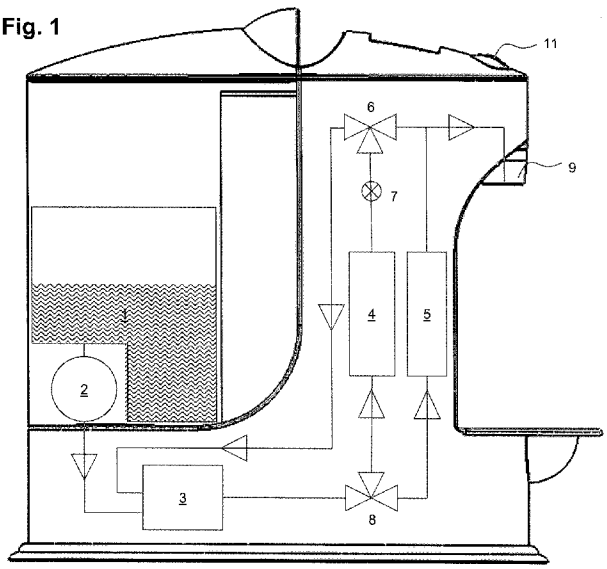
(54) **Title:** ELECTRICAL APPLIANCES

Fig. 1



(57) **Abstract:** An electric flow-through liquid dispenser including means for avoiding retaining liquid between the dispensing outlet and a heater or cooler. Instead, the liquid may be recirculated through the heater or cooler in the next dispensing operation. Alternatively, the liquid may be evacuated before the next dispensing operation. Alternatively, the heater or cooler may be disposed immediately behind the outlet, so that the retained volume of liquid is minimized. A flow-through heating apparatus comprising a heated flow path and a downstream depressurising means is also disclosed. Also disclosed is a superheated steam generator using a flow- through heater.

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Electrical Appliances

The present invention relates to electrically powered liquid dispensing apparatus.

Background to the Invention

One known form of liquid dispensing apparatus is a flow-through heater, in which water is heated on demand; see for example patent publication US-A-7151892.

Such flow-through heaters have some advantages over electric kettles, in that hot water is dispensed almost instantly, and only the required amount of water is heated.

Another form of liquid dispensing apparatus is a water cooler, in which water is cooled on demand as it is dispensed. Some forms of water dispensing apparatus include both heating and cooling options.

One problem with liquid dispensing apparatus is that liquid may remain in or behind the dispensing outlet after a first dispensing operation and be dispensed at the beginning of the next dispensing operation. This problem occurs particularly with continuous flow-through heaters, in which liquid is pumped or otherwise forced continuously through a heating portion while the liquid is dispensed. When the dispensing operation is stopped, liquid remains downstream of the heater or cooler, so is not heated or cooled as desired. Hence, particularly when only a small quantity of liquid is dispensed, that liquid is not at the required temperature.

Another problem with such remaining liquid is that it may remain in or behind the dispensing outlet for a considerable time, during which it may deposit scale. Furthermore, this remaining liquid is not sealed from the outside environment, which is unhygienic.

Another problem with liquid dispensing apparatus is that liquid is not dispensed instantly on demand, since there is a delay while the heater or cooler is energised and an initial quantity of liquid is heated from room temperature to the required temperature.

Another problem with liquid dispensing apparatus, particularly heating apparatus, is that a dispensing operation may be initiated accidentally, or by a child, thereby posing a safety risk.

Liquid dispensing apparatus may include a filter arranged to filter the liquid on demand ; hence, the reservoir must be drained in order to change the filter. Another problem is that is it not easy to determine when the filter needs changing.

Currently available liquid dispensing apparatus also suffer from ergonomic problems. For example, the positioning of the dispensing outlet and drip tray restricts the size or height of receptacle into which the liquid can be dispensed. As another example, the reservoir may be located at the top of the apparatus so that the overall height of the apparatus restricts where the apparatus may be positioned or installed. As another example, a display indicating the state of the apparatus may be difficult to read, depending on the positioning of the apparatus.

In some applications, it is desirable to dispense liquid at boiling point, or as a gas (e.g. steam). For example, US 6,224,755 discloses a coffee maker in which coffee is prepared by passing steam initially through the coffee grounds, followed by hot water. This is achieved by means of a controllable outlet valve.

WO 2005/080885 A1 discloses a flow-through heater comprising a heater plate and a base structure displaceable away from the heater plate so that steam can be generated within the heater.

Heating a liquid to boiling in a flow-through heater presents various problems. For example, if water boils within a flow-through heater, scale may be deposited within the heater which will affect the efficiency of the heater or block the flow-through path altogether. Descaling of flow-through heaters is a generally inconvenient process. Another problem is that steam is a poor thermal conductor, so the heater may over-heat if steam is generated within it.

Statement of the Invention

According to one aspect of the present invention, there is provided an electric flow-through liquid dispenser including means for avoiding retaining liquid between the dispensing outlet and a heater or cooler. Instead, the liquid may be recirculated through the heater or cooler in a dispensing operation. Alternatively, the liquid may be evacuated before a dispensing operation. The liquid may be evacuated through the dispensing outlet, for example into a drip tray, or switched to an alternative outlet.

Alternatively, the heater or cooler may be disposed immediately behind the outlet, so that the retained volume of liquid is minimized.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler with an outlet coated internally with a scale inhibiting coating, such as silver.

According to another aspect of the invention, there is provided an electric flow-through heater or cooler which includes a filter arranged to prevent or substantially reduce the build up of scale in the heater or cooler, and/or in a dispensing outlet

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler including a filter arranged outside the supply of liquid, and replaceable without accessing the supply.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler including a base which contains a liquid supply and/or the heating or cooling part.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler including means for indicating the operational status thereof by means of a lighting effect, preferably arranged at or around a part to which the operational status relates.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler including means for displaying the operational status thereof on an upper surface, the display being rotatable about a substantially vertical axis.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler including a safety lock for preventing accidental operation and/or operation by a child.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler including means for mixing an additive with the liquid before dispensing.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler that is activated by placing a receptacle under an outlet thereof.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler with an outlet that is adjustable in position.

According to another aspect of the invention, there is provided an electric flow-through liquid heater or cooler with a pre-heated reservoir.

According to another aspect of the invention, there is provided an electric flow-through kettle.

According to another aspect of the invention, there is provided an electrically powered flow-through heater having a heating portion arranged to heat liquid flowing therethrough, means downstream of the heating portion for maintaining the liquid within the heating portion at an elevated pressure and an outlet for dispensing the liquid heated by the heater at a lower pressure, such that the liquid is dispensed at or above boiling point but boiling within the heating portion is substantially prevented.

According to another aspect of the invention, there is provided a liquid sterilizing apparatus comprising a first reservoir for containing unsterilized liquid, a flow-through heater for heating the liquid and thereby sterilizing it, and a secondary reservoir for receiving sterilized liquid from the flow-through heater. The liquid may be kept warm within the secondary reservoir, or may be chilled or allowed to cool. In this last alternative, the liquid may be chilled by a flow-through chiller on dispensing.

According to another aspect of the invention, there is provided apparatus for generating superheated steam, in which steam is generated and then superheated by means of a flow-through heater.

Brief Description of the Drawings

Embodiments of the invention will now be described with reference to the drawings identified below.

Figure 1 is a diagram of a liquid dispensing apparatus according to a first embodiment of the invention.

Figure 2 is a diagram of a liquid dispensing apparatus according to a second embodiment of the invention.

Figure 3a is a diagram of a liquid dispensing apparatus according to a third embodiment of the invention.

Figure 3b is a perspective view of the liquid dispensing apparatus according to the third embodiment.

Figure 4 is a diagram of a liquid dispensing apparatus according to a fourth embodiment of the invention.

Figure 5 is a perspective diagram of a liquid dispensing apparatus according to a fifth embodiment of the invention.

Figure 6 is a diagram of a moveable outlet arrangement which may be applied to the embodiments of the invention.

Figure 7a is a perspective view of a liquid dispensing apparatus including a further feature comprising a rotatable display.

Figures 7b and 7c are plan views of the liquid dispensing apparatus of Figure 7a in different operating configurations.

Figures 8a and 8b are diagrams illustrating a further feature of the embodiments, comprising an interchangeable reservoir.

Figure 9 is a diagram of an alternative embodiment in which a liquid dispensing apparatus is plumbed into a water main.

Figure 10 is a schematic diagram of a flow-through heater and depressurising means in third to fifth embodiments of the invention.

Figure 11 is a plan view of a flow-through heater and depressurising means according to a second embodiment, in the plane D-D of Figure 12.

Figure 12 is a cross-sectional view of the flow-through heater and depressurising means of the second embodiment, in the plane C-C of Figure 11.

Figure 13 is a plan view of a flow-through heater and depressurising means according a third embodiment.

Figure 14 is a cross-section in the plane A-A of the flow-through heater of Figure 13.

Figure 15 is a partial cross-section in the plane B-B of Figure 13.

Figure 16 is a partial cross-section in the plane C-C of Figure 13.

Figure 17 is a plan view of an unheated channel plate forming part of the depressurising means of the third embodiment.

Figures 18a and 18b are respectively perspective and axial cross-sectional views of a flow-through heater and depressurising means in a fourth embodiment.

Figures 19a and 19b are respectively perspective and axial cross-sectional views of a flow-through heater and depressurising means in a fifth embodiment.

Figure 20 is a schematic diagram of a superheated steam generating apparatus in a sixth embodiment of the invention.

Figure 21 is a schematic diagram of an experimental arrangement of a steam generator in the sixth embodiment.

Detailed Description of Embodiments

Water Dispenser - First Embodiment

In the first embodiment shown in Figure 1, water is stored in a water reservoir 1 at the rear of the apparatus, to the left of the diagram. The reservoir 1 is preferably removable and the apparatus is arranged to inhibit dispensing unless the reservoir 1 is in place.

When a dispensing operation is initiated, for example by user actuation of a dispensing actuator 11, a pump 3 draws water from the reservoir 1 through a filter 2. The flow of water through the apparatus is controlled by first and second three-way valves 6, 8, and the direction of flow through each connection (e.g. water pipe) is shown by an arrow. Operation of the apparatus is controlled by an electrical, electronic or mechanical controller (not shown).

In a heating mode, water is drawn through a heater 4 and the temperature of water leaving the heater 4 is detected by a thermostat 7. The first three-way valve 6 is controlled so that water circulates between the pump 3 and the heater 4 until the thermostat detects that the water has reached a predetermined temperature, whereupon the water is then dispensed through an outlet 9. The heater 4 may have a variable heating rate and/or the pump 3 may have a variable flow rate, controlled in accordance with the output of the thermostat 7 so that water is dispensed at the required

temperature. The heater may be substantially as described in WO 2005/080885 A1, mentioned above, or WO 2007/037694 A1.

In a cooling mode, water is drawn through a chiller 5 before it is dispensed through the outlet 9. A further thermostat may be provided in the cooling path and the chiller 5 and/or pump 3 controlled so that water is dispensed at the required temperature.

In either case, the required temperature may be fixed at the time of manufacture, or may be preset by the user.

In either mode, when the dispensing operation is completed, the pump 3 continues to operate for a short while and the first three-way valve 6 is switched over so that water remaining between the heater 4 or chiller 5 and the outlet 9 is withdrawn from the outlet 9 back towards the pump 3. When the next dispensing operation is initiated, the remaining water is circulated through the heater 4 or chiller 5 according to the mode required. The remaining water may be circulated once, or recirculated through the heater 4 or chiller 5 until it reaches the desired temperature. As a result, the water is dispensed at the required temperature from the beginning of the dispensing operation.

In an alternative embodiment, the remaining water may be evacuated from the apparatus rather than being recirculated. For example, the flow arrangement may include an air valve that allows air into the vicinity of the outlet 9 at the end of the dispensing operation, so that the remaining water flows out through the outlet 9 or through a waste outlet (not shown). Preferably, the evacuation is controlled automatically by the controller. For example, when the dispensing operation is completed, the controller may open the air valve immediately so that the remaining water flows through the outlet 9 and is therefore dispensed as part of the dispensing operation. Alternatively, the controller may delay the evacuation by a predetermined interval, so that if there is no further dispensing operation during that interval, the evacuation then takes place automatically. The remaining water may then be evacuated into a drip tray under the outlet 9. Alternatively, the controller may sense the temperature of the remaining liquid, and evacuate it when the temperature diverges by a predetermined extent from the desired temperature.

The controller may be programmed with one or more control programs arranged to provide the operations of the controller described herein. The control program(s) may

be provided as a computer program product. The controller may be reprogrammable via an external interface accessible to a service engineer, or to the user.

In an alternative embodiment, the heater 4 and/or chiller 5 may be positioned immediately behind the outlet 9, such that the volume of remaining water is very slight and no recirculation or evacuation thereof is required.

In an alternative embodiment, a small auxiliary heater may be provided around the outlet 9 to keep the remaining water warm between dispensing operations; the heater may be a trace heater, preferably a self-regulating trace heater.

The filter 2 may be designed so as to soften the water, for example by removing calcium and/or magnesium ions. Advantageously, this may prevent or reduce the build-up of scale within the liquid dispensing apparatus. The filter 2 may alternatively or additionally be designed to improve the taste of the water, for example by removing chlorine. The filter 2 may alternatively or additionally be designed to purify the water, for example by filtering out suspended particles and/or organisms.

As an alternative to a filter, other means of achieving any of the above effects may be used, such as a UV sterilizer for purifying the water.

As an alternative to the pump 3, there may be provided other means for causing the liquid to flow through the heater 4 or chiller 5 and out of the outlet 9. For example, the bottom of the reservoir 1 may be raised sufficiently that the liquid is driven through the apparatus by the head of liquid. Alternatively, the reservoir 1 may be pressurised, for example by a gas cylinder or a pump actuable to raise the pressure within the reservoir 1, or by means of exerting pressure on or within the boundary of the reservoir such as to reduce the volume of the reservoir and thereby increase the pressure therein, such as an elastic wall or diaphragm.

Water Dispenser - Second Embodiment

The second embodiment, as shown in Figure 2, differs from the first embodiment in that the filter 2 is positioned outside the reservoir 1, and in this example downstream of the pump 3, before the second three-way valve 8. In this way, the filter 2 can be made accessible from a 'dry' area of the apparatus, so that the filter 2 can be changed without emptying the reservoir 1. For example, the filter 2 may be removable from one side of

the apparatus. A further advantage is that the filter 2 does not occupy space within the reservoir 1, which therefore has a larger capacity for a given overall size.

Advantageously, purifying means that use radiation, such as a UV sterilizer, may be positioned downstream of the reservoir 1, and may be shielded within the apparatus to reduce the risk of a user being exposed to potentially harmful radiation.

In a variant of the second embodiment, there may be provided an additional flow path that selectively bypasses the filter 2, thus allowing the user the option to dispense unfiltered water.

The speed of the pump 3 may be reduced so that water of low quality can be filtered or sterilized more effectively. Alternatively, water may be recirculated through the filter 2, or selectively circulated through a second filter (not shown).

Water Dispenser - Third Embodiment

Figures 3a and 3b show a third embodiment of the invention, which differs from the first and second embodiments in that the reservoir 1, filter 2, pump 3 and heater 4 are housed in a base 12 on which a receptacle 13 rests to receive the dispensed heated water. The first three-way valve 6, thermostat 7 and outlet 9 are located at the end of a tap or spout 14. In this way, the height of the apparatus is much reduced although, as shown in Figure 3b, the footprint is somewhat increased.

The internal flow arrangement in the third embodiment is similar to that of the first embodiment, except that there is no chiller 5 and hence no need for the second three-way valve 8. Moreover, the filter 2 is positioned outside the reservoir 1 and can therefore be replaced without emptying the reservoir 1.

In this embodiment, the heater 4 is mounted horizontally rather than vertically as in the first and second embodiments; however, in other embodiments the heater 4 may be mounted in other orientations.

Water Dispenser - Fourth Embodiment

The fourth embodiment, as shown in Figure 4, differs from the third embodiment in that the internal flow arrangement allows water to be recirculated through the filter 2. Hence, the remaining water is filtered before being reheated during the next dispensing operation. This may reduce problems of hygiene with the remaining water.

Water Dispenser - Fifth Embodiment

The fifth embodiment, as shown in Figure 5, is a development of the second embodiment in which the filter 2 is provided as a removable cartridge accessible from the side of the apparatus. It can therefore be changed without the user getting his or her hands wet by accessing the inside of the reservoir 1, or requiring the reservoir 1 to be emptied. Other features of the fifth embodiment, as described below, may also be applied to the first embodiment, or other embodiments.

Mains Connection

The reservoir 1 is fillable through a hose 16, which may be connected to a water main. There may be provided within the reservoir 1 a valve for refilling the reservoir 1 from the hose 16 when the water level within the reservoir falls below a minimum level.

Status Indication

The apparatus includes a control panel 15 comprising a display, such as an LCD, for displaying the status of the apparatus, for example one or more of the following:

- the estimated remaining life of the filter 2
- whether the apparatus is in heating or cooling mode
- whether the water level in the reservoir 1 is below a minimum level
- the number of dispensing operations since a predetermined event, such as descaling
- the volume of liquid dispensed, either during the current operation, the previous operation, or the total volume dispensed since a predetermined event.
- the estimated time to dispense a predetermined volume of liquid, given the current operating parameters of the apparatus
- Pre set temperature setting
- Altitude setting
- Drip tray full
- Status of additive(s)
- Fault mode – to prompt user action and/or servicing

- Steam mode (see further embodiments below)

Alternatively or additionally, status information may be indicated audibly, such as:

- an audible warning to change the filter 2
- an audible indication of whether the apparatus is in heating or cooling mode
- an audible warning that the water level in the reservoir 1 is below a minimum level
- an audible warning that descaling is required
- an audible indication of the volume of water dispensed during the current operation, such as a rising or falling tone as water is dispensed.

Alternatively or additionally, status information may be indicated by a lighting effect, such as:

- a visual warning to change the filter 2
- a visual indication of whether the apparatus is in heating or cooling mode
- a visual warning that the water level in the reservoir 1 is below a minimum level
- a visual warning that descaling is required
- a visual indication of the volume of water dispensed during the current operation, such as a lighting effect that changes colour (e.g. from green to red) and/or intensity as water is dispensed.

Lighting effects may be provided by illumination of the dispensing area 10, the reservoir 1 and/or other parts of the apparatus. Preferably, the lighting effect is provided in the area to which the indication relates, for example:

- illumination of the dispensing area 10 to indicate whether the apparatus is in heating or cooling mode (e.g. red for heating, blue for cooling)
- illumination of the reservoir 1 to indicate whether the water level is below a minimum level (e.g. green for above the level, red for below)
- illumination in or around the filter 2 to indicate that the filter 2 needs changing.

Alternatively, the lighting effect may be provided in an area most likely to attract the user's attention, such as an indication in the dispensing area 10 that the water level in the reservoir 1 is below the minimum.

Safety Features

The dispensing area 10 includes a movable door 16, and the apparatus is arranged to operate only when the door 16 is closed and a receptacle 13 is detected in the dispensing area, for example by a microswitch. The door 16 may be hinged, or form part of a turntable on which the receptacle is supported. Rotation of the turntable rotates the door 16 into a closed position.

User Control

The apparatus may also include one or more user operable controls, such as buttons 17, that allow additional control of the apparatus by the user. For example, the user may select a predetermined quantity of liquid to be dispensed, such as a cup-, mug- or jugfull. The user control may have a 'learning mode', whereby a user keeps a button pressed until the required volume of liquid is dispensed. When the button is released, the quantity of liquid dispensed is stored in a memory within the control and may be assigned to a preset control by the user.

The control may include a timer, so that the user may set the apparatus to dispense liquid at a predetermined time or after a predetermined interval.

The user operable control may implement one or more safety features. For example, the apparatus may include a safety lock whereby the dispensing actuator 11 is disabled. The safety lock may only be removed by pressing a predetermined combination of the control buttons 17. The predetermined combination may be variable e.g. programmable by a parent. Alternatively, the apparatus may be provided with a biometric sensor, such as a fingerprint sensor provided in the dispensing actuator 11, such that a dispensing operation may only be initiated by a recognised person pre-programmed into the apparatus.

Additive

The apparatus may include one or more separate reservoirs for additives, which may be beverage ingredients such as a cordial or squash concentrate or instant tea or coffee powder. The flow arrangement within the apparatus may include a valve for mixing the ingredient to the water on demand, so that a beverage may be dispensed instead of water, according to a selection by the user. The rate or quantity of additive to be mixed may be varied by the user, so as to control the strength of the beverage. Preferably, the flow arrangement allows flushing out of the diluted beverage when changing from a beverage dispensing mode to a water dispensing mode.

Other examples of additives that may be added from the separate reservoir include: a water purifying additive, such as iodine or chlorine; and a water improvement additive, such as fluoride, iodine, folic acid, vitamins or minerals.

Alternatively or additionally, the reservoir 1 may contain a premixed beverage, such as diluted squash or cordial, or pre-made tea or coffee. The beverage may be pre-mixed by the user, or the reservoir 1 may be a disposable or returnable container supplied filled with the premixed beverage.

Alternatively or additionally, the apparatus may be arranged to pass heated liquid through a brewing chamber, containing tea or coffee for example. The brewing chamber may be arranged to house a disposable pod, bag or filter, for brewing tea, coffee or another beverage. The brewing chamber may be immediately behind the outlet 9.

Storage

The housing of the apparatus may include a storage area for storing tea, coffee, sugar and/or other beverage ingredients for addition to the water after dispensing. For example, the apparatus may include a pull-out storage drawer towards the base, around the dispensing area 10. One or more additional reservoirs for additives, as described above, may be accessible in one or more compartments towards the base, allowing easy checking and refilling of the additional reservoir

The housing of the apparatus may include one or more storage areas for crockery and/or utensils, such as cups and spoons. At least one of the storage areas may be heated, for example so as to pre-heat cups for hot beverages. The heating may be provided by waste heat from the heater 4 and/or the chiller 5.

Dispensing arrangements

The dispensing actuator 11 may be provided around the outlet 9 within the dispensing area, so that a dispensing operation may be initiated by pressing the receptacle 13 up against the dispensing actuator 11. This allows a quick one-handed dispensing operation. Alternatively, the dispensing actuator may comprise a detector within the dispensing area 10, that detects the presence of the receptacle 13.

The dispensing area 10 may include a drip tray. The drip tray may be stowed in the dispensing area when not in use. The drip tray may be removable and storable in the reservoir 1 for transportation. The drip tray may include a float switch so that the apparatus can detect and indicate to the user when the drip tray is full. Alternatively, the drip tray may include a float that provides a direct visual indication that the drip tray is full.

The outlet 9 may be adjustable in height and/or angle so that a receptacle 13 fits under the outlet 9 without the outlet being too high above the top of the receptacle, thus minimizing the risk of splashing. The outlet 9 may be telescopic or otherwise retractable so as to minimize the quantity of water remaining in the outlet 9. Alternatively, there may be provided a plurality of interchangeable outlets 9, having different lengths and/or features (such as for example the provision of a brewing chamber as described above). The interchangeable outlets 9 may be mounted on a common carrier such that they can be interchanged by rotating or sliding the carrier, for example. Alternatively, the interchangeable outlets may be discrete 9 and interchangeable by means of a common fitting, such as a screw or bayonet fitting.

A further additional feature is shown in Figure 6, in which the outlet 9 is provided on a moveable arm 18 that can be stowed so that the outlet 9 is within the dispensing area 10 in order to fill a small receptacle 13a that fits within the dispensing area 10, or can be moved out of the dispensing area 10 in order to fill a larger receptacle 13b, such a teapot or coffee pot. In this example, the arm 18 pivots laterally, but in an alternative the arm 18 may move vertically to accommodate tall receptacles.

There may alternatively or additionally be provided multiple outlets 9, connectable in parallel to the flow-through heater, with a valve arranged to direct the output of the flow-through heater to a selected one or more of the outlets 9. For example, one of the

outlets 9 may include a brewing chamber and be used to dispense tea or coffee, while another is used solely to dispense hot water, thus avoiding tainting hot water with residue from previous beverage dispensing.

The outlet 9 may be coated internally with a scale-inhibiting material, such as silver plating. The coating may alternatively or additionally be selected to inhibit bacterial or other microbial growth, for which silver is also a suitable material.

The apparatus may include a feature to guide the receptacle 13a, 13b into position under the outlet 9, such as a portion of the housing shaped to conform to the receptacle 13a, 13b when in position under the outlet 9.

Rotatable Display

Figure 7 shows a further additional feature in which the control panel 15 is rotatably mounted on the main body of the apparatus. This arrangement facilitates positioning of the apparatus against a back wall 20 in two different arrangements, either end-on with the reservoir 1 facing towards the back wall 20, as shown in Figure 7b, or side-on as shown in Figure 7c, with the support 19 rotated by 90° so that the display 15 is oriented correctly towards the user.

Alternatively, substantially the entire apparatus may be rotatably mounted, for example on a base. The base may be a cordless power base, or a simple turntable; in the latter case, means may be provided for restricting the rotation so as to prevent tangling of the power cord.

In either case, the rotation may be performed manually, or may be driven by the apparatus, for example by an electric motor.

Pre-heated Reservoir

In the above embodiments, the reservoir 1 contains water at ambient temperature. Alternatively, the reservoir 1 may include a heater and thermostat for pre-heating the water to a predetermined temperature lower than the desired dispensing temperature. For example, the pre-heating temperature may be 40°C for a dispensing temperature of 95°C. Advantageously, pre-heating the water reduces the time taken to heat the water up to dispensing temperature on demand. In addition, preheating the water increases the flow rate at the dispensing temperature. Preferably, the pre-heating temperature is

significantly lower than the dispensing temperature, for energy efficiency. Alternatively, the pre-heating temperature may be sufficiently high for making beverages of certain types, such as 80°C which is suitable for making coffee or reconstituting packet soups and the like. Preferably, the reservoir 1 is thermally insulated to reduce the energy required to maintain the water at the pre-heating temperature.

The heater for pre-heating the reservoir may comprise an immersed or under-floor heater. The heater may comprise a sheathed heating element, a thick film heating element and/or a light-emitting element such as a halogen heater. The light-emitting element may provide an automatic indication of the heating of the reservoir 1, and preferably is arranged to illuminate the liquid within the reservoir.

As an alternative, the heater 4 may be used to pre-heat the water in the reservoir 1; the flow arrangement includes an outlet from the heater 4 to the reservoir 1, and the water is circulated through the reservoir until it reaches the required temperature, as detected by the thermostat 7.

One application of this embodiment is in a Turkish teamaker, comprising a hot water reservoir 1 and a brewing container, such as a teapot; typically, the brewing container is kept warm by being positioned above the hot water reservoir 1. In a further development, however, the hot water may be circulated through a warming circuit in direct thermal contact with the brewing container, such as around or under the brewing container. When water is dispensed from the heated reservoir, the flow of hot water may be switched away from the warming circuit and towards the outlet 9.

Flow-through Heater Kettle

As another alternative, the reservoir 1 may be used as a kettle, so that no dispensing outlet 9 is required. Water is circulated through the heater 4 until the desired temperature is reached, and the reservoir 1 is then removed and the heated water poured directly from it. The input to and output from the reservoir 1 may each include a valve so that water does not leak from the reservoir 1 when removed from the apparatus, although the input to the reservoir 1 may be provided above the maximum water level, in which case no valve is required.

This arrangement may reduce the noise often associated with kettles having heating elements located within the water reservoir. Moreover, the arrangement provides greater design freedom than conventional kettles. For example, the reservoir 1 itself need contain very few parts, and may be easily washable.

Where the heater 4 and thermostat 7 are arranged to heat the water to boiling, the heater 4 is preferably located downstream of the pump 3, to avoid boiling within the pump 3, which would reduce efficiency.

Flow-through Sterilizer

As the liquid passes through the heater 4, it is heated to a high temperature which may be sufficient to sterilize the liquid. However, as the liquid is then recirculated into the reservoir 1, it is mixed with unsterilized liquid and the effect of sterilization is lost. In the flow-through heater kettle described above, the liquid may eventually be sterilized if the contents of the reservoir 1 are brought to boiling point and boiled for an extended period, such as a minute or more.

In an alternative embodiment, liquid is not recirculated to the reservoir but is instead passed into a secondary reservoir prior to dispensing. Liquid contained in the secondary reservoir has all passed through the heater 4 and may therefore be sterilized. The liquid in the secondary reservoir may be maintained at a predetermined temperature prior to dispensing, for example by a keep warm heater. Alternatively, the liquid may be allowed to cool within the secondary reservoir and dispensed at ambient temperature, or chilled prior to dispensing.

Interchangeable Reservoirs

Figures 8a and 8b show a further feature of the apparatus in which the reservoir 1 is interchangeable, for example with a bottle holder 20 for supporting a large bottle forming the reservoir 1 as shown in Figure 8a, or with a larger reservoir 1 as shown in Figure 8b. The apparatus may be dockable onto the bottle holder 20 and/or the larger reservoir 1, for example by sliding the apparatus into position so that the larger reservoir 1 or bottle holder 20 does not need to be lifted. The larger reservoir 1 may be fillable by means of a jug, or directly from a water main. The bottle may be supplied containing a pre-mixed beverage, as described above.

Water Main Connection

As shown in Figure 9, in an alternative embodiment the reservoir 1 may be connected to a water main 21 by means of a permanent connection, instead of by the hose 16. Alternatively, in some embodiments water may be supplied directly from the water main 21 without the intermediate reservoir 1. In this case, the mains pressure may be sufficient to force the water through the apparatus, without the need for the pump 3 or other pressurizing means. Either arrangement may be used in 'point of use' applications.

Flow-through heater with Depressurising means

A flow-through heater suitable for supplying boiling water or steam (or, more generally, boiling liquid or gas) will now be described. It is generally know that the boiling point of a liquid increases with pressure; the following embodiments of a flow-through heater make use of this dependence to dispense boiling water and/or steam while substantially preventing boiling within the heated portion of the flow-through heater. Water within the heated portion of the flow-through heater is maintained at a pressure elevated above ambient pressure, and is dispensed at a lower pressure, such as ambient pressure, either as boiling water or steam.

A schematic diagram of the arrangement of the flow-through heater is shown in Figure 10, in which a pump 3 pumps water at elevated pressure into the inlet 24 of flow-through heater 4; a temperature sensor 23 at the outlet 25 of the heater 4 provides an input to a controller 40 arranged to control the speed of the pump 3 and/or the heating power of the heater 4 so as to maintain a predetermined temperature at the outlet 25. Water passing out of the heater 4 flows through a depressurising means 22 arranged to maintain a pressure difference between the inlet 26 and outlet 27 thereof; the outlet may be at ambient pressure. The controller 40 may also control the depressurising means 22 so as to vary the pressure drop over it.

The pressure difference over the depressurising means 22 and the temperature at the outlet 25 of the heater 4 are such as substantially to prevent boiling within the flow-through heater 4, while allowing boiling water and/or steam to be dispensed at the outlet. Preferably, the pressure difference is at least 0.2 bar, and most preferably at least 0.4 bar. In one example, the temperature at the outlet 25 of the heater 4 is maintained at

approximately 104°C and the pressure at the outlet 25 of the heater 4 at approximately 1.4 bar, where the outlet 27 of the depressurising means 22 is at 1 bar. Hence, water will not boil until it passes through the depressurising means 22.

The pressure at the outlet 27 may vary, for example with variations in barometric pressure caused by changing weather conditions or height above sea level. The pump 3 and/or heater 4 and/or depressurising means 22 may be controlled to compensate for the variations so as to achieve a consistent output at the outlet 27, such as water that is always just at boiling point. The compensation may be performed manually, or automatically by sensing atmospheric pressure, or deriving it using local GPS data for example.

Instead of the pump 3, alternative pressurizing means may be used as explained above with reference to the previous embodiments.

The heater 4 may be a flow-through heater substantially as described in WO 2007/037694 A1, or as in the embodiments of WO 2005/080885 A1 that do not allow boiling within the heater 4.

In a first embodiment, the depressurising means 22 comprises an overpressure or pressure release valve. The valve is designed to open when a pressure greater than a predetermined threshold is applied across it. For the above example, the threshold may be 0.4 bar. Hence, the water boils as it is dispensed through the valve. As an alternative to a valve, a fine nozzle could be used as the depressurising means 22.

The valve or nozzle may be adjustable such that the pressure drop across it is variable. This is turn varies the temperature at which the water leaves the valve or nozzle. The adjustment may be made manually, or automatically under the control of the controller 40; this provides an alternative or additional means of controlling the temperature and/or flow rate of the water.

However, the use of a valve or nozzle as the depressurising means 22 may lead to problems. For example, the valve or nozzle may become clogged with scale. Also, the valve may provide an intermittent pressure release, as the pressure difference rises above the threshold and then falls below it as the valve opens; dispensing may not be even, and the valve may emit sudden bursts of boiling water or steam.

To overcome these problems, in the following embodiments the depressurising means 22 comprises a substantially unheated flow path arranged downstream of the heater 4. The unheated flow path provides resistance to the flow of water so that the pressure of the water drops gradually as it passes along the unheated flow path. Hence, the water gradually begins to boil as it passes along the unheated flow path and the boiling water or steam may be dispensed smoothly.

Since boiling takes place in the unheated portion of the flow path, scale tends not to adhere to the flow path, but is purged with the boiling water. The unheated flow path may include material that inhibits scale formation, such as polypropylene.

The unheated flow path may be comparatively long, narrow and/or convoluted so as to provide the necessary degree of resistance. Alternatively, the unheated flow path may comprise a component that presents a high resistance to water flow, such as a filter or a chamber or pod containing finely comminuted and/or tightly packed beverage ingredients, such as finely ground tea leaves or coffee grounds, or powdered beverage. The latter alternative is preferred for beverages that tolerate being heated to boiling, such as tea.

The unheated flow path may comprise a part of an appliance in which the flow-through heater 4 is used, and need not be integrated or supplied as a unitary component with the flow-through heater 4. For example, the unheated flow path may comprise part of an appliance as described above with reference to Figures 1 to 9. Where water at a sub-boiling temperature is desired, the depressurising means 22 may be switched out of the flow path, to allow higher flow rates or to avoid the problem of unheated water being retained downstream of the heater 4 after a dispensing operation, as described above. In other words, water may be selectively dispensed directly from the outlet 25, or from the outlet 27.

A second embodiment, as shown in Figures 11 and 12, is based on a spiral flow-through heater as disclosed in WO 2005/080885 A1. Water enters the inlet 24 of a spiral flow path 28, along which the water passes over an element plate 29 and emerges through a central outlet 27. The element plate 29 has a heated radially outer portion 29a and an unheated radially inner or central portion 29b. In this way, a radially outer section of the flow path 28 passing over the heated portion 29a functions as the heater 4, and a

radially inner section of the flow path 28 passing over the unheated portion 29b functions as the depressurising means 22. Preferably, the temperature sensor 23 is provided at the boundary between the heated portion 29a and the unheated portion 29b; for example, as shown in Figure 12, the sensor 23 may be mounted on the underside of the element plate 29, or alternatively, on the upper side of the element plate 29 or in another position within the flow path 28. The sensor 23 may be an NTC thermistor.

The element plate 29 is preferably a thick film element plate; the radially outer portion 29a is provided with thick film heating tracks, while the radially inner portion 29b may be substantially free of thick film heating tracks, or be provided with heating tracks or some other heating means which are independently switchable from those in the radially outer portion. Alternatively, the element plate 29 may be provided with a sheathed heater under the radially outer portion, and means to inhibit heat diffusion into the radially inner portion 29b. For example, a heat diffuser provided under the radially outer portion 29a does not extend under the radially inner portion 29b.

As shown in Figure 12, the flow path 28 may be formed by spiral-wound strips 31 and 32 held between the element plate 29 and a base plate 30, such that the strip 31 forms the side walls of the flow path 28, the element plate 29 forms the bottom, and the strip 32 forms the top. The element plate 29 and base plate 30 are held within a housing 33, which is arranged to press the element plate 29 and base plate 30 together and to seal their peripheries, to provide a watertight seal between the strip 31 and the element plate 29. Biasing means may be provided within the housing to achieve this pressure. For example, there may be provided a spring member between the base plate 30 and the housing 33, to bias the base plate 30 towards the element plate 29.

The strip 32 maintains the winding spacing of the strip 31, and may be secured against the base plate 30. Preferably, the strips 31 and 32 are of flexible material and are mounted to allow for thermal expansion of the heating element 29. Either or both of the strips 31 and 32 may be of thermally conductive material, such as metal, or plastic. As an alternative to the strip 32, there may be provided a rigid or flexible matrix that holds the strip 31 in position. The matrix may be of metal or plastic. Alternatively, the base plate 30 and strips 31 and 32 may be replaced by an integrated channel plate 34, which is formed of a material such as metal or plastic so as to define the inlet 24, flow path 28

and outlet 27, and is pressed against the element plate 29 so as to close the underside of the flow path 28.

The flow path 28 may be formed by various alternative methods, including die casting, injection moulding, brazing, welding, pressing and the like. For high pressure applications, the strip 31 may be immovably sealed against the element plate 29 and/or the base plate 30, for example by welding, brazing or soldering.

A third embodiment, as shown in Figures 13 to 17, uses substantially all of the area of the element plate 29 for heating, but includes an unheated flow path displaced from the element plate 29. The heated flow path and the unheated flow path are arranged in displaced, parallel planes, contained within a common housing.

As shown most clearly in Figure 14, the third embodiment includes a spiral-wound flow-through heater 4 similar to the second embodiment, except that the radially inner portion 29b of the element plate 29 is heated, and hence is also similar to the flow-through heater disclosed in WO 2005/080885 A1. However, water flowing through the central outlet 25 of the flow-through heater 4 flows into a central inlet 26 of an unheated channel plate 34, through a connection that is made water-tight and pressure-resistant by a seal 36, such as an O-ring

The unheated channel plate 34, as shown in Figure 17, defines a spiral flow path 35 that leads from a central inlet 26 to a peripheral outlet 27. The spiral flow path 35 is dimensioned so as to provide sufficient resistance so as to constitute the depressurising means 22 in this embodiment. The flow-through heater 4 and unheated channel plate 34 are held together within a housing 33. A spring 70 is provided between the base plate 30 and the channel plate 34, so as to bias the base plate 30 towards the element plate 29, and the channel plate 34 towards the housing 33. A seal, sealing sheet or diaphragm 39, made for example of rubber, may be provided between the channel plate 34 and the housing 33, to seal against the outer face of the unheated channel plate 34 and thereby to form one side of the spiral flow path 35. Alternatively, a spring may be provided between the diaphragm 39 and the housing 33. Alternatively, the unheated channel plate 34 may seal directly against the housing 33. Alternatively, the spiral flow path 35 may be formed within the housing 33, or defined by the shape of a part of the housing 33 that seals against the base plate 30 of the flow-through heater 4.

In an alternative embodiment, the unheated channel plate 34 may be spaced apart or otherwise thermally insulated from the flow-through heater 4, to avoid heating of the unheated channel plate 34. The thermal insulation may be provided by an additional diaphragm, seal and/or spacer, for example against or forming part of the base plate 30.

There may be provided a diaphragm between the flow path 28 and the unheated flow path so as to reduce the pressure in the unheated flow path by the Venturi effect.

The housing includes an inlet port 37 arranged to convey water to the inlet 24 as shown in Figure 15, and an outlet port 38, arranged to convey boiling water and/or steam from the outlet 27, as shown in Figure 16. Since both the inlet 24 and the outlet 27 are at the periphery of the heater 4 and unheated channel plate 34 respectively, the inlet and outlet ports 37 and 38 may also be arranged at the periphery of the housing 33, which allows the complete assembly to be constructed with a low profile.

In certain applications it will be necessary for the decompression tube to flow directly over the heating element and these may be sealed by a diaphragm to overcome thermal expansion and contraction issues.

In a fourth embodiment, shown in Figures 18a and 18b, the flow-through heater comprises a cylindrical inner body 40 having a helical projection 44 on the outer surface thereof. A thermally conductive outer cylindrical sleeve 42 is formed or fitted around the inner body 40 so as to contact the helical projection 44 and thereby form a helical flow path 28 between the inlet 24 and the outlet 27. This flow path 28 is substantially longer than the inner body 40 or the sleeve 42.

Adjacent an upstream section of the helical flow path, a thick film heater 4 is formed on the outer surface of the sleeve 42, so that the upstream section of the flow path 28 is heated. The remaining surface of the sleeve 42 is not heated, so that a downstream portion of the helical path 28 is unheated and thereby forms the depressurising means 22 in this embodiment.

The sleeve 42 may be formed of metal, such as stainless steel, having an electrically insulating layer onto which the thick film heating tracks are deposited, or of ceramic material onto which the tracks are deposited directly. Advantageously, the material on which the heater 4 is formed should have a low adherence of scale, high strength, low heat capacity and high thermal conductivity, such as titanium, aluminium, copper,

stainless steel, or ceramic. The inner body 40 may be formed of a material having high strength, low heat capacity, low thermal conductivity and low scale adherence. Liquid-facing surfaces may be coated with a material that inhibits scale formation.

The helical projection 44 may be formed integrally with the inner body 40, for example by hydroforming or moulding. Alternatively, the helical path 28 may be formed by a groove or recess in the cylindrical sleeve 44 and/or the inner body 40. Alternatively, the helical projection 44 may be formed by a wire wound around the inner body 40 or fixed to the inner surface of the outer sleeve 42. Alternatively, the helical path 28 may be formed by a cylindrical channel structure placed between the sleeve 42 and the inner body 40, analogous to the channel plate 34 in the third embodiment. The channel structure may be compressed between the sleeve 42 and the inner body 40, for example by constructing the inner body 40 of resilient material and fitting an expandable member within the inner body 40.

A fifth embodiment, shown in Figures 19a and 19b, differs from the fourth embodiment in that the heater 4 covers substantially all of the outer surface of the cylindrical sleeve 42 substantially all of the helical path 28 is heated. The depressurising means 22 in this embodiment comprises an unheated helical flow path 50 formed around a central cylindrical body 46 within the inner body 40. The inner wall of the inner body 40 is provided with an insulating layer 48, or is formed of thermally insulating material, so as to reduce heat transfer between the heated flow path 28 and the unheated flow path 50.

Hence, water passes through the inlet 24, along the heated helical flow path 28 between the outer sleeve 42 and the inner body 40, and then passes into the inner body 40 to flow along the unheated helical flow path 50 between the central body 46 and the inner body 40, emerging from the outlet 27 at the same end of the flow-through heater as the inlet 24. The fifth embodiment provides a particularly compact arrangement, in circumstances where a cylindrical form of flow-through heater is preferred.

In a modification of the fifth embodiment, an outlet port may be provided at the outlet 25 of the heated flow path 28, together with a three-way valve switchable between a first position in which water flow out of the outlet port from the heated flow path 28, and a second position in which the water continues into the unheated flow path 50.

The heater 4 may alternatively be a sheathed element heater or heating wire wound around the sleeve 42. The heater may alternatively be provided in or around the central body 46 and the functions of the flow path 28 and the flow path 50 are reversed, as is the flow direction of the water.

In the fourth and fifth embodiments described above, the outer sleeve 42 and inner body 40 are right circular cylindrical, but other types of cylindrical shapes may be used.

The helical flow path 28 and/or 50 may include baffles or projections perpendicular to the flow path to promote turbulent flow. The flow path 28 and/or 50 may have a convoluted shape other than a helical shape. As an alternative, there may be provided a narrow cylindrical gap between the sleeve 42 and the inner body 40 or between the inner body 40 and the central body 46. Preferably, one or both sides of the gap are profiled to promote turbulent flow, for example by means of baffles projecting into the gap. Preferably the pump 3, or other means for providing water at pressure at the inlet 24,is controlled to provide a minimum flow rate through the flow path 28 and/or 50 to promote turbulent flow and avoid laminar flow.

The resistance per unit length of the flow path constituting the depressurising means may progressively decrease along the flow path, for example by progressively increasing the cross-sectional area or pitch of the flow path. Where the flow path comprises a narrow gap, the width of the gap may increase along the flow path, for example by tapering the sleeve 42, inner body 40 and/or central body 46.

Flow-through heater for superheating steam

In a sixth embodiment, illustrated schematically in Figure 20, pressurized steam is provided to the inlet 24 of the flow-through heater 4, which superheats the steam to produce superheated steam at the outlet 25. The pressurized steam is generated by a steam generator 80, which is supplied with liquid. A temperature sensor 23 at the outlet 25 of the heater 4 provides an input to a controller 40 arranged to control the steam generator 80 and/or the heating power of the heater 4 so as to maintain a predetermined temperature at the outlet 25.

Preferably, the steam generator 80 generates steam substantially free from liquid. An experimental arrangement to achieve this is illustrated in Figure 21. A reservoir 51 is filled with water and sealed. The lower portion of the reservoir 21 is partitioned into a

separate water chamber 52 by a float valve 53, which controls the water level in the water chamber 52. The water chamber 52 communicates with a steam chamber 57 by means of a water communication tube 54, whereby the level of water in the steam chamber 57 is equalised with that in the water chamber 52. An air tube 11 equalises the pressure in the water chamber 52 with the surrounding atmospheric pressure. A pressure communication tube 60 equalises the pressure between the reservoir 51 and the steam chamber 57.

At the bottom of the steam chamber 57 there is provided a heating element 56, comprising an element plate with an underfloor heater, preferably a thick film heater. Power is provided to the heating element 56 via a contact bridge 55. The water communication tube 54 maintains a thin layer (about 5 mm) of water on the heating element 56, thus allowing the water to heat up quickly to boiling (in around 30 seconds) and then to boil continuously without allowing the element 56 to boil dry.

Saturated steam at around 100°C is released from the top of the steam chamber 57 by a pressure valve 58. The pressure of the steam is measured by a pressure gauge 59 in this experimental arrangement, but the steam pressure may be input to the controller 4 in the embodiment shown in Figure 20.

The steam is then superheated by the flow-through heater 4, which may be a spiral flow-through heater substantially as disclosed in WO 2005/080885 A1, although preferably baffles are provided within the spiral channel so as to slow the flow of steam; the baffles may be provided by a spring arranged within the channel. In one experimental example, the flow-through heater 4 draws 320 W and outputs superheated steam at up to 260°C at only 0.25 bar overpressure. Superheated steam is produced very quickly, within 60 seconds of starting the apparatus.

Set-up

In the above embodiments, the controller may be programmed to perform an initial set up procedure to determine the limits of the operating parameters of the apparatus, given the conditions of operation such as altitude and/or liquid type and/or type of the outlet 9 where this is interchangeable. For example, the controller may vary the power of the heater 4 and/or the flow rate of the pump 3 and/or the pressure drop of the depressurising means 22 and/or the pressure of the steam generator 80 during a test

dispensing operation, while reading the temperature at the outlet 23 and optionally at the outlet 9 and thereby determine operating limits beyond which the liquid will start to boil within the heater 4 and/or within the depressurising means 22, the latter applying if the apparatus is not intended to dispense steam or gas. The controller then applies corresponding limits to the operating parameters during subsequent dispensing operations to ensure that the liquid will not start to boil within the heater 4 and/or within the depressurising means 22. The temperature at the outlet 9 may be sensed by a sensor such as an NTC thermistor.

The set up procedure may be rerun periodically, or in response to a detected change in conditions of operation, to ensure that the unit operates optimally for the current conditions.

Alternatively or additionally, the apparatus may include alternative means for sensing steam at the outlet 23 and/or the outlet 9.

User Variable Operation

The appliance may be arranged to dispense boiling water or water at one or more sub-boiling temperature, according to a selection by the user. For example, the power output of the heater 4 and/or the flow rate of the pump 3 and/or the pressure drop of the depressurising means 22 may be controlled by the controller so as to dispense water at the desired temperature.

The depressurising means 22 may be controlled so as to vary the pressure drop, for example so that for higher flow rates and/or lower temperatures the pressure is reduced and for lower flow rates and/or higher temperatures the pressure is increased. In the first embodiment described above, the depressurising means 22 may comprise an adjustable valve or nozzle. In the subsequent embodiments, the resistance of the unheated flow path may be varied, for example by varying the length by switching out one or more sections, or by switching between a series and a parallel arrangement.

Alternatively or additionally, there may be provided a mixer that mixes liquid heated by the heater 4 or cooled by the chiller 5 with liquid taken directly from the reservoir 1 without heating or chilling. In this way, liquid may be dispensed at the desired temperature without the need to control the rate of heating or cooling of the liquid. The

mixer may be controlled manually, or automatically by the controller to achieve the desired temperature.

In one example, an appliance may be arranged to dispense water at a selected one of a plurality of temperatures, such as 100°C for brewing tea, 90°C for brewing 'pod' type coffees, 80°C for instant coffee or for brewing coffee, 60°C for instant porridge, 40°C for baby milk, 10 °C for cooled water etc.

The flow rate may also be varied by the user so as to control the strength of the beverage being brewed. This is particularly important for brewing coffee, where the strength of the brewed coffee is dependent on the flow rate of water through the coffee grounds.

Applications

The flow-through heater arrangements described above may be used in many different types of appliance, including those described above with reference to Figures 1 to 9. Although the embodiments have been described above primarily in the context of heating water, at least some of the embodiments may be applied to the heating of other liquids, such as oil in a fryer, solvent in a cleaning appliance, or liquids that are required to be dispensed in industrial processes at or close to boiling. The same appliance may be designed to heat any one of a plurality of different liquids, with the temperature at the outlet 25 of the heater 4 and/or the pressure difference of the depressurising means 22 being selectable according to the type of liquid to be dispensed. Examples of appliances in which embodiments of the invention may be incorporated include on-demand tea makers or coffee makers, including high-pressure (9 bar or more) espresso makers such as those currently sold under the Nespresso® brand, low pressure (2-5 bar) coffee makers such as those sold under the Tassimo® brand, 'teawakers' such as sold under the Teasmade® brand, water dispensers beverage vending machines, water dispensers, dishwashers and the like.

The flow-through heater 4 and optionally the depressurising means 22 may be provided as a modular unit, to which various different types of reservoir 1 and/or outlet 9 are connectable for different applications, for example as described herein. The different types of reservoir may include means to indicate to the unit what type of liquid they contain. The pump 3 or other pressurizing means may be provided within the modular

unit, or may be provided separately. Examples include a steam-generating unit interchangeably connectable to a wallpaper stripper or steam iron attachment as the outlet 9.

The modular unit may comprise additional components as well as the heater 4 and the pump 3, such as one or more control circuits, pressure relief valves, bypass valves, flow regulators, thermistors etc, so that the modular unit may easily be incorporated in an appliance while requiring a minimum amount of further development by the appliance manufacturer.

Alternatively, flow-through heater units may be provided as modules that can be combined in series and/or parallel to provide for example, higher power flow-through heating appliances or better temperature control.. An arrangement of multiple flow-through heater units in parallel is particularly advantageous, in that each of the modular units may be provided with a separate power supply drawing for example 2-3 kW and allowing only a slow flow rate, but the flow rates of the units may be combined at the outlet 9 to provide a high flow rate. In one embodiment each individual unit may comprise at least a flow-through heater 4 and pump 3, and optionally depressurising means 22, but other components such as the reservoir 1 and outlet 9 may be shared between the different units.

In another embodiment one pump 3 supplies the flow for all the units, and power may be selectively switched to one or more of the units, to control the output temperature.

The modules could each be small low-power units (e.g. 200 watts) to achieve a total output of 2 - 3 kW. Alternatively each module could be a high power (2-3kW) unit, in which case the total output would be significantly larger, for example 21 kW, suitable for point of use water heaters.

The individual modules could use any suitable type of heating means, for example a tube incorporating a thick film printed track or alternatively a complete flow-through heater assembly, for example as shown in Figure 14.Appliances according to embodiments of the invention may provide steam either as a primary function, such as a steam cleaner or as a secondary function, such as a steam milk frother for making cappuccino coffee. Appliances may have the option to dispense hot water or steam, either through the same outlet or through different outlets 9.

Other appliances that may incorporate the embodiments that dispense steam or other gas include wallpaper strippers, steam irons, water purifiers, food steamers, dishwashers, floor cleaner, carpet, curtain or furniture cleaners and sterilization equipment for medical, dentistry or food sterilisation applications. The appliance may be portable, or form part of a domestic, industrial, commercial or laboratory processing unit.

An embodiment that generates steam at the outlet 9 may be used to generate steam in a Turkish bath or installed into a sauna to ensure the correct humidity. Alternative applications include a steam generator for a microwave or standard ovens and a stand-alone food steamer. The steam generator may collect and recirculate condensed water for generating more steam. In some cooking applications, the appliance may spray hot or boiling water onto the food, rather than steam.

The sixth embodiment, in which superheated steam is generated, is particularly suitable for cooking, as the superheated steam rapidly conducts heat onto the food to be cooked. As the steam is superheated, there is little condensation on the food, so that the embodiment is applicable to 'dry frying', where food is cooked rapidly at high temperature without fat or oil, thus providing a healthy alternative to fried food. Superheated steam is also particularly applicable to sterilizing, degreasing and cleaning applications.

A portable appliance in an embodiment of the invention may include a small reservoir 1 containing liquid that is heated by recirculation through the flow-through heater 4, as described above. Such an appliance may have a low power rating, such as 500 W, and operate at 12 or 24 Volts for use in a car, truck or boat, without a voltage converter.

The portable appliance may include or be connectable to a reservoir containing pre-mixed beverage, as described above. The reservoir may comprise a bottle having a standardised opening or connector for connection to the portable appliance. The liquid may be heated by recirculation, or by passing steam through the reservoir, generated from a separate water reservoir. The need for the pump 3 may be avoided by providing an arrangement for raising the reservoir 1 so as to pressurise the liquid, for example using a portable stand.

The above embodiments illustrate, but do not limit, the present invention. Alternative embodiments which may occur to the skilled reader on reading the above description may also fall within the scope of the invention.

Claims

1. Apparatus for generating superheated steam, comprising

   a. a steam generator; and

   b. a flow-through heater arranged to receive steam from the steam generator and to superheat the steam.

2. The apparatus of claim 1, wherein the steam generator is arranged to generate steam substantially free of liquid.

3. The apparatus of claim 2, wherein the steam generator comprises a steam chamber including a heater and means for supplying liquid to the heater for generating steam.

4. The apparatus of claim 3, wherein the means for supplying liquid is arranged substantially to balance the supply of liquid with the conversion of the liquid into steam.

5. The apparatus of claim 3 or claim 4, wherein the heater is an underfloor heater provided in the bottom of the steam chamber.

6. The apparatus of claim 5, wherein the means for supply of liquid is arranged to keep the underfloor heater covered with said liquid.

7. The apparatus of any one of claims 3 to 6, wherein the steam generator is arranged to output steam from an upper part of the steam chamber.

8. The apparatus of claim any one of claims 1 to 7, wherein the steam generator is arranged to output steam above atmospheric pressure.

9. The apparatus of any one of claims 1 to 8, wherein the flow-through heater comprises an elongate heated flow path.

10. The apparatus of claim 9, wherein the flow path is arranged in a spiral.

11. The apparatus of claim 9 or 10, wherein the flow path includes one or more baffles.

12. The apparatus of any one of claims 9 to 11, wherein the flow-through heater comprises an element plate in thermal contact with the heated flow path.

13. The apparatus of claim 12, wherein the element plate is a thick film element plate.

14. A flow-through liquid heater, comprising in series a first, substantially cylindrical heated flow path and a second, substantially cylindrical unheated flow path downstream of the first flow path.

15. The liquid heater of claim 14, wherein the first and/or second flow path comprises a helical flow path.

16. The liquid heater of claim 14 or claim 15, wherein the first and/or second flow path is formed between substantially concentric cylindrical inner and outer bodies.

17. The liquid heater of claim 16, wherein the first and second flow paths are provided between the substantially concentric cylindrical bodies, at least one of the inner and outer bodies comprising heating means for heating the first flow path.

18. The liquid heater of claim 17, wherein the heating means comprises one or more thick film heating tracks.

19. The liquid heater of claim 16 or claim 17, including a substantially cylindrical central body within and substantially concentric with the inner body, wherein one of the first and second flow paths is provided between the inner and outer bodies and the other of the first and second flow paths is provided between the inner and central bodies.

20. The liquid heater of any one of claims 14 to 19, wherein the first and/or second flow paths include projections substantially perpendicular to the direction of flow so as to promote turbulent flow.

21. The liquid heater of any one of claims 14 to 20, wherein the resistance per unit length of the second flow path decreases along the direction of flow.

22. The liquid heater of any one of claims 14 to 21, wherein the second flow path comprises depressurising means for causing a pressure difference between liquid flowing through the first flow path and liquid leaving the second flow path, such that the liquid leaves the second flow path at or above boiling point, but is substantially prevented from boiling within the first flow path.

23. A flow-through liquid heating apparatus comprising:

a. a heated flow path arranged to heat liquid flowing therethrough

b. and depressurising means downstream of the heated flow path for causing a pressure difference between liquid flowing through the heated flow path and liquid leaving the depressurising means, such that the liquid leaves the depressurising means at or above boiling point, but is substantially prevented from boiling within the heated flow path.

24. Apparatus according to claim 23, including pressurizing means for pressurizing the liquid prior to flowing through the heated flow path.

25. Apparatus according to claim 23 or claim 24, including control means for controlling the apparatus such that the liquid leaves the depressurising means substantially at a predetermined desired temperature.

26. Apparatus according to claim 25, including a sensor arranged to sense the temperature of the liquid leaving the heated flow path, the control means being arranged to maintain the sensed temperature substantially at a predetermined level.

27. Apparatus according to claim 26, wherein said predetermined level is selectable by a user.

28. Apparatus according to any one of claims 25 to 27, each when dependent on claim 24, wherein the control means is arranged to control the pressurizing means.

29. Apparatus according to any one of claims 25 to 28, wherein the control means is arranged to control the flow rate of the liquid.

30. Apparatus according to any one of claims 25 to 29, wherein the control means is arranged to control the heating level of the heated flow path.

31. Apparatus according to any one of claims 25 to 30, wherein the control means is arranged to control the depressurising means.

32. Apparatus according to any one of claims 25 to 31, wherein the control means is arranged to perform an initial dispensing operation so as to determine a limit to the operating parameters for a subsequent dispensing operation.

33. Apparatus according to any one of claims 25 to 31, wherein the control means is arranged to perform the initial dispensing operation in response to a change in operating conditions of the apparatus.

34. Apparatus according to any one of claims 23 to 31, wherein the depressurising means comprises a high-resistance component.

35. Apparatus according to claim 34, wherein said high-resistance component comprises a valve.

36. Apparatus according to claim 34, wherein said high-resistance component comprises a nozzle.

37. Apparatus according to claim 34, wherein said high-resistance component comprises a filter.

38. Apparatus according to claim 34, wherein said high-resistance component comprises a beverage ingredient.

39. Apparatus according to any one of claims 23 to 38, wherein the depressurising means comprises a substantially unheated flow path.

40. Apparatus according to claim 39, wherein the depressurising means is integrated with the heated flow path.

41. Apparatus according to claim 39 or claim 40, wherein the heated flow path and the unheated flow path comprise first and second portions of an elongate flow path.

42. Apparatus according to claim 41, wherein the first portion is in thermal contact with a heated portion of an element plate.

43. Apparatus according to claim 42, wherein the second portion is thermally isolated from the heated portion of the element plate.

44. Apparatus according to claim 43, wherein the second portion is displaced from the element plate.

45. Apparatus according to any one of claims 41 to 44, wherein the first portion is substantially planar.

46. Apparatus according to any one of claims 41 to 45, wherein the first portion is arranged in a spiral.

47. Apparatus according to any one of claims 41 to 46, wherein the second portion is substantially planar.

48. Apparatus according to any one of claims 41 to 47, wherein the second portion is arranged in a spiral.

49. Apparatus according to any one of claims 41 to 44, wherein the first and/or second portion is substantially cylindrical.

50. Apparatus according to claim 49, wherein the first and/or second portion is substantially helical.

51. Apparatus according to claim 50, wherein the first and second portions comprise a helical flow path.

52. Apparatus according to claim 51, wherein the helical flow path is arranged between an inner cylinder and an outer sleeve, and a heater is provided on the outer sleeve adjacent the first portion.

53. Apparatus according to claim 49, wherein the second portion is substantially helical and arranged substantially within the first portion.

54. Apparatus according to claim 38, wherein the unheated flow path comprises a dispensing outlet.

55. Apparatus according to any one of claims 23 to 54, wherein the depressurising means is switchable out of the flow path.

56. Apparatus according to claim 55 when dependent on claim 25, wherein the control means is arranged to switch the depressurising means out of the flow path.

57. Apparatus according to claim 55 or 56, wherein the control means is arranged to ensure that liquid leaves the heated flow path at a predetermined desired temperature when the depressurising means is switched out of the flow path.

58. Apparatus according to any one of claims 23 to 57, including a filter for preventing or reducing deposit from the liquid within the flow path.

59. A method of operating the apparatus of any one of claims 25 to 31, or any one of claims 32 to 58 when dependent on claim 25, comprising controlling the apparatus such that the liquid leaves the depressurising means substantially at a predetermined desired temperature.

60. The method of claim 59, when dependent on claim 32 or 33, comprising performing said initial dispensing operation.

61. A computer program product comprising program code means arranged to perform the method of claim 59 or 60.

62. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. control means for controlling the means for heating or cooling so as to vary the temperature at which the liquid is dispensed, in accordance with a user selection.

63. The apparatus of claim 62, wherein the control means is arranged to control the flow rate of the liquid.

64. The apparatus of claim 62 or claim 63, wherein the control means is arranged to control the heating or cooling level of the means for electrically heating or cooling.

65. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. user operable control means for controlling the dispensing operation so as to dispense a predetermined quantity of said liquid, said predetermined quantity being variable by the user.

66. The apparatus of claim 65, wherein said predetermined quantity is determined by the user as being substantially equal to a quantity dispensed in a previous dispensing operation.

67. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

user operable control means for controlling the rate of dispensing of the liquid.

68. The apparatus of claim 67, wherein the apparatus includes a brewing chamber through which the liquid passes during dispensing.

69. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. means for mixing the heated or cooled liquid with liquid that has not been heated or cooled, before dispensing from the dispensing outlet.

70. Apparatus according to claim 65, wherein the means for mixing is controlled by a controller such that the dispensed liquid is substantially at a predetermined temperature.

71. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet; and

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation;

wherein the dispensing outlet comprises means for interchangeably connecting any one of a plurality of different outlet portions.

72. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet; and

c. a plurality of discrete heating or cooling means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation;

wherein the plurality of discrete heating or cooling means are arranged in series and/or in parallel between the liquid supply and the dispensing outlet.

73. The apparatus of claim 72, wherein the discrete heating or cooling means are arranged in series.

74. The apparatus of claim 72, wherein the discrete heating or cooling means are arranged in parallel.

75. The apparatus of any one of claims 72 to 74, wherein the discrete heating or cooling means are selectively switchable so as to vary the heating or cooling respectively of the liquid.

76. The apparatus of any one of claims 72 to 75, wherein the discrete heating or cooling means are provided as modular units.

77. The apparatus of claim 76, wherein the modular units are individually separable from the apparatus.

78. An integrated flow-through heater module comprising at least a pump, heating means and one or more of a depressurising means, a control circuit, a pressure relief valve, a bypass valve, a flow regulator and a thermistor.

79. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. means for removing liquid remaining between the heating or cooling means and the outlet after the dispensing operation.

80. The apparatus of claim 79, wherein the means for removing remaining liquid is arranged to recirculate the remaining liquid through the means for electrically heating or cooling, during a subsequent dispensing operation.

81. The apparatus of claim 80, wherein the remaining liquid is recirculated until it reaches a predetermined temperature.

82. The apparatus of claim 80 or 81, including a filter arranged between the liquid supply and the means for electrically heating or cooling the liquid.

83. The apparatus of claim 82, wherein the means for removing remaining liquid is arranged to recirculate the remaining liquid through the means for electrically heating or cooling and through the filter, during a subsequent dispensing operation.

84. The apparatus of claim 79, wherein the means for removing remaining liquid is arranged to evacuate the remaining liquid after the dispensing operation.

85. The apparatus of claim 84, wherein the means for removing remaining liquid is arranged to evacuate the remaining liquid from the dispensing outlet after the dispensing operation.

86. The apparatus of claim 85, wherein the means for removing remaining liquid is arranged to evacuate the remaining liquid from the dispensing outlet at a predetermined interval after the dispensing operation.

87. The apparatus of claim 85, wherein the means for removing remaining liquid is arranged to evacuate the remaining liquid from the dispensing outlet in response to the temperature of the remaining liquid.

88. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. an auxiliary heater for warming liquid remaining between the heating or cooling means and the outlet after the dispensing operation.

89. An electric liquid sterilising apparatus, comprising:

a. a first reservoir for containing unsterilized liquid;

b. a flow-through heater for heating the liquid and thereby sterilizing it, and

c. a secondary reservoir for receiving sterilized liquid from the flow-through heater.

90. The apparatus of claim 89, including means for maintaining the liquid within the secondary reservoir at a predetermined temperature.

91. The apparatus of claim 89 or 90, including means for dispensing liquid from the second reservoir and means for chilling the liquid as it is dispensed.

92. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet; and

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation, arranged immediately behind the outlet.

93. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet; and

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation;

wherein an internal surface of the outlet is coated with a scale-inhibiting material.

94. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet; and

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation;

wherein an internal surface of the outlet is coated with a microbe-inhibiting material.

95. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. a filter arranged outside the liquid supply.

96. The apparatus of claim 95, including a pump for pumping the liquid from the supply to the outlet, wherein the filter is arranged downstream of the pump.

97. The apparatus of claim 95 or claim 96, including means for selectively bypassing the filter.

98. The apparatus of any one of claims 95 to 97, wherein the filter is removable without requiring access to the supply.

99. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. sterilizing means arranged outside the liquid supply, for sterilizing the liquid.

100. The apparatus of claim 99, wherein the sterilizing means is arranged to sterilize the liquid by irradiation.

101. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet; and

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation;

wherein the liquid supply is provided in a base below the dispensing outlet.

102. The apparatus of claim 101, wherein the means for electrically heating or cooling is provided in the base.

103. The apparatus of claim 101 or claim 102, wherein the dispensing outlet is provided above the base.

104. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. means for indicating the operational status of a part of the apparatus;

wherein the means for indicating comprises means for providing a lighting effect at or around said part.

105. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. a display for displaying the operational state of the apparatus;

wherein the display is provided on an upper surface of the apparatus and is rotatable about a substantially vertical axis.

106. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation;

d. a dispensing actuator for initiating the dispensing operation; and

e. a safety lock for preventing initiation of the dispensing operation unless at least one additional criterion is met.

107. The apparatus of claim 106, including moveable means for restricting access to the dispensing outlet, the safety lock being arranged to prevent actuation of the dispensing actuator unless the moveable means is in position.

108. The apparatus of claim 106 or claim 107, including means for detecting a receptacle arranged to receive liquid from the dispensing outlet, the safety lock being arranged to prevent actuation of the dispensing actuator unless said receptacle is detected.

109. The apparatus of any one of claims 106 to 108, including a biometric sensor, the safety lock being arranged to prevent actuation of the dispensing actuator unless the biometric sensor identifies an authorised user.

110. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. means for mixing the liquid from the supply with an additive prior to dispensing.

111. The apparatus of claim 110, wherein the means for mixing is selectively operable to mix the liquid with an additive.

112. The apparatus of claim 111, wherein the concentration of additive mixed with the liquid is variable by the user.

113. The apparatus of claim 111 or 112, including means for flushing out the liquid after mixing with the additive.

114. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. a dispensing actuator for initiating the dispensing operation, the dispensing actuator being actuable by placing a receptacle in a position for receiving liquid from the dispensing outlet.

115. An electric liquid dispensing apparatus, comprising:

a. a liquid supply;

b. a dispensing outlet;

c. means for electrically heating or cooling the liquid between the supply and the outlet during a dispensing operation; and

d. means for adjusting the position of the dispensing outlet.

116. The apparatus of claim 115, wherein the means for adjusting is arranged to move the outlet in a substantially horizontal direction.

117. The apparatus of claim 115 or claim 116, wherein the means for adjusting is arranged to move the outlet in a substantially vertical direction.

118. The apparatus of any one of claims 65 to 117, wherein the liquid supply comprises a mains water supply.

119. The apparatus of any one of claims 65 to 118, wherein the liquid supply comprises a reservoir.

120. The apparatus of claim 119, wherein the reservoir is interchangeable with a holder for an alternative reservoir.

121. The apparatus of claim 119, wherein the reservoir is connectable to a mains water supply.

122. The apparatus of claim 121, including means arranged to supply liquid from the mains water supply to the reservoir when the level of liquid in the reservoir falls below a predetermined threshold.

123. An electric liquid dispensing apparatus, comprising:

a. a liquid reservoir;

b. a dispensing outlet;

c. means for electrically heating the liquid between the reservoir and the outlet during a dispensing operation; and

d. means for pre-heating the liquid within the reservoir.

124. The apparatus of claim 123, wherein the means for pre-heating comprises means for circulating liquid between the reservoir and the means for electrically heating the liquid.

125. The apparatus of claim 123, wherein the means for pre-heating comprises a secondary heater.

126. The apparatus of claim 125, wherein the secondary heater is a light-emitting element.

127. The apparatus of any one of claims 123 to 125, including means for thermally insulating the reservoir.

128. The apparatus of any one of claims 123 to 127, including a brewing container arranged to be heated by the pre-heating of the liquid within the reservoir.

129. The apparatus of claim 128, including means for circulating liquid from the reservoir into direct thermal contact with the brewing container.

130. The apparatus of claim 128, wherein the brewing container is arranged to be heated by the liquid within the reservoir.

131. An electric liquid heating apparatus, comprising:

a. a liquid reservoir;

b. an electric heater outside the reservoir, and

c. means for circulating liquid between the reservoir and the heater.

132. The apparatus of claim 131, wherein the liquid reservoir is detachable from the electric heater and the means for circulating liquid.

133. The apparatus of any one of claims 65 to 132, including means for storing at least one beverage ingredient.

134. The apparatus of any one of claims 65 to 132, including means for storing at least one item of crockery and/or one or more utensils.

135. The apparatus of claim 133 or 134, wherein said means for heating or cooling the liquid is arranged to provide heat to the means for storing so as to heat the contents thereof.

136. Apparatus according to any one of claims 65 to 133, wherein the electric heater or means for electrically heating the liquid comprises apparatus according to any one of claims 23 to 57.

137. Apparatus substantially as herein described with reference to any one of Figures 1 to 9 of the accompanying drawings.

138. Apparatus substantially as herein described with reference to Figure 10 of the accompanying drawings.

139. Apparatus substantially as herein described with reference to Figures 11 and 12 of the accompanying drawings.

140. Apparatus substantially as herein described with reference to Figures 13 to 17 of the accompanying drawings.

141. Apparatus substantially as herein described with reference to Figure 17 of the accompanying drawings.

142. Apparatus substantially as herein described with reference to Figures 18a and 18b of the accompanying drawings.

143. Apparatus substantially as herein described with reference to Figures 19a and 19b of the accompanying drawings.

144. Apparatus substantially as herein described with reference to Figure 20 of the accompanying drawings.

145. Apparatus substantially as herein described with reference to Figure 21 of the accompanying drawings.

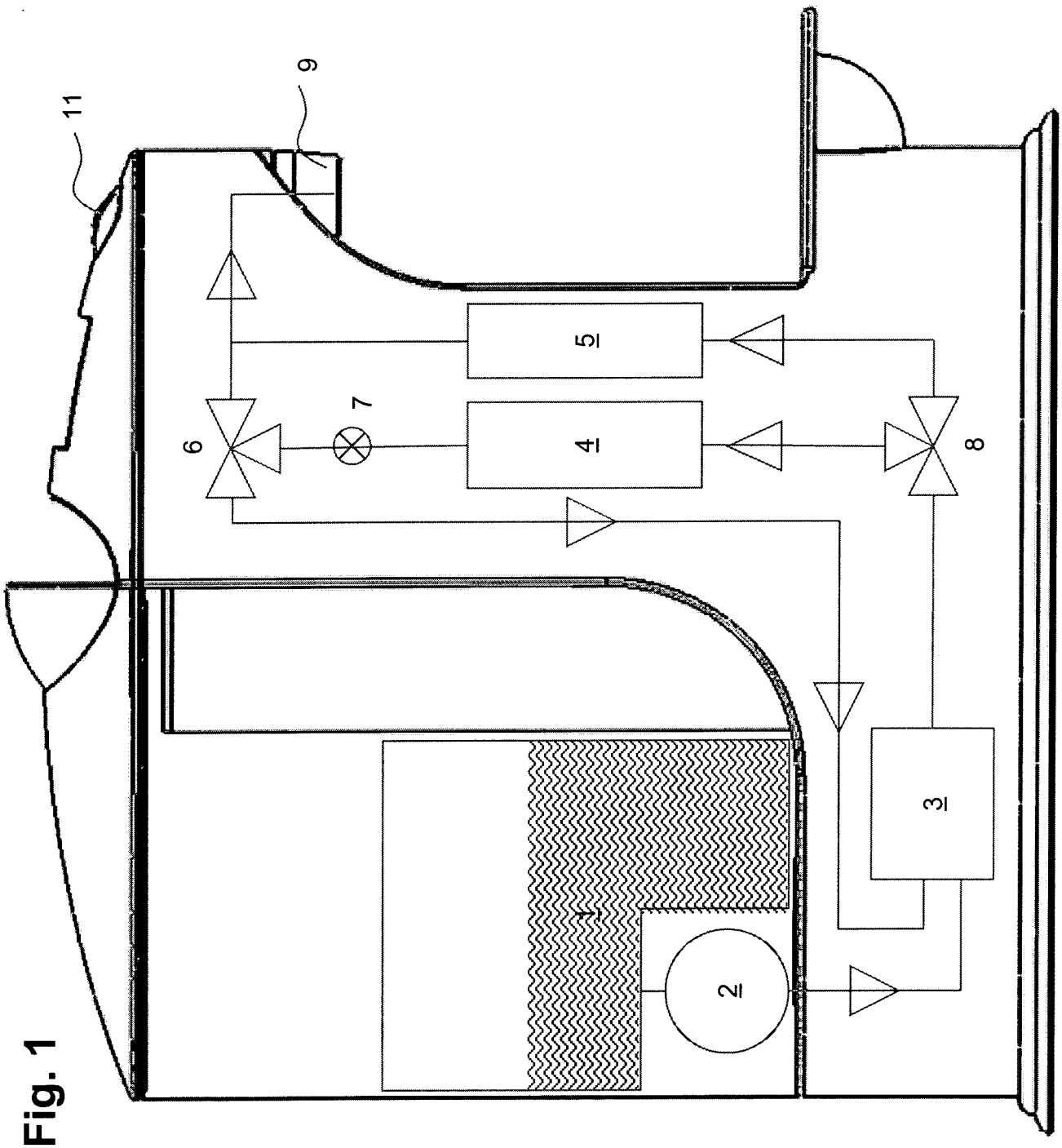


Fig. 1

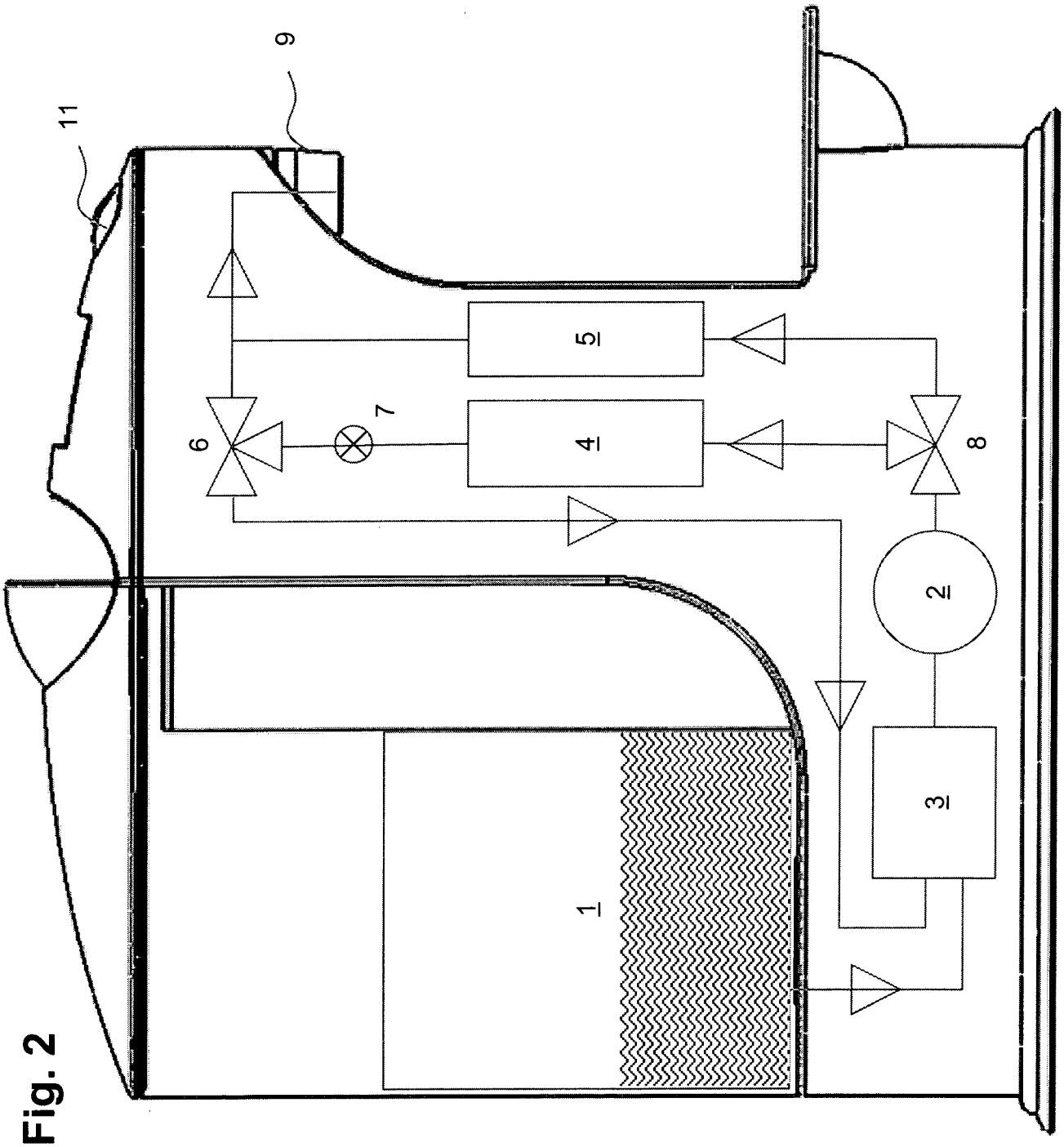


Fig. 2

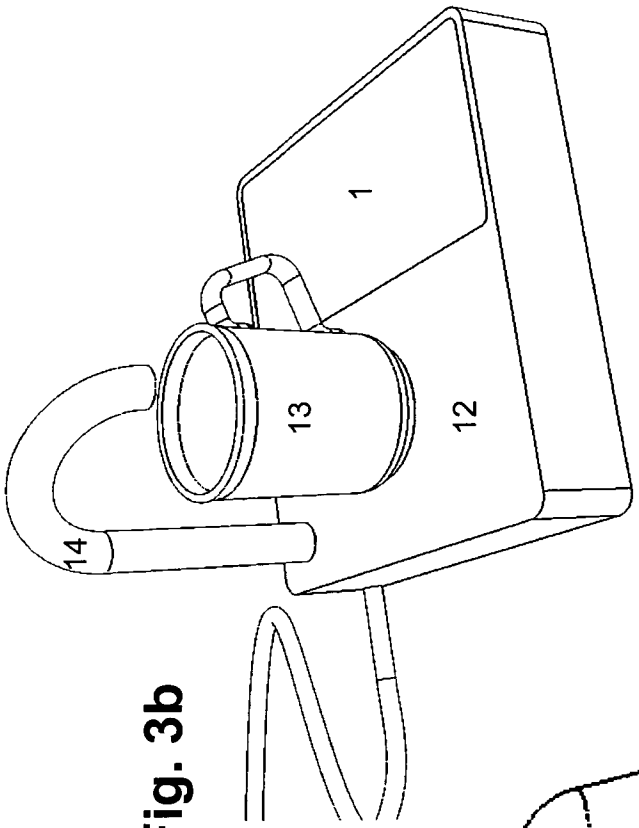


Fig. 3b

Fig. 3a

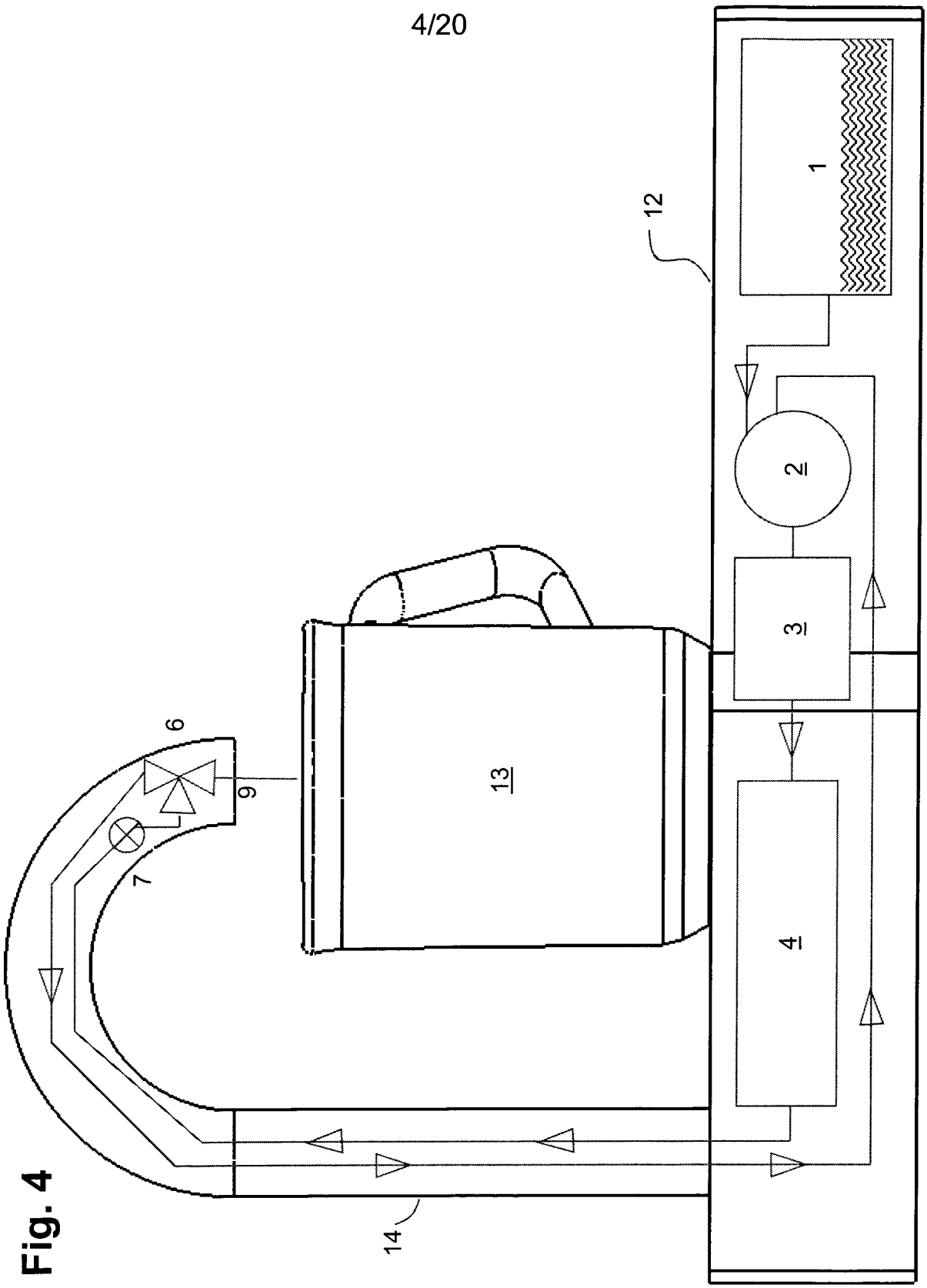


Fig. 4

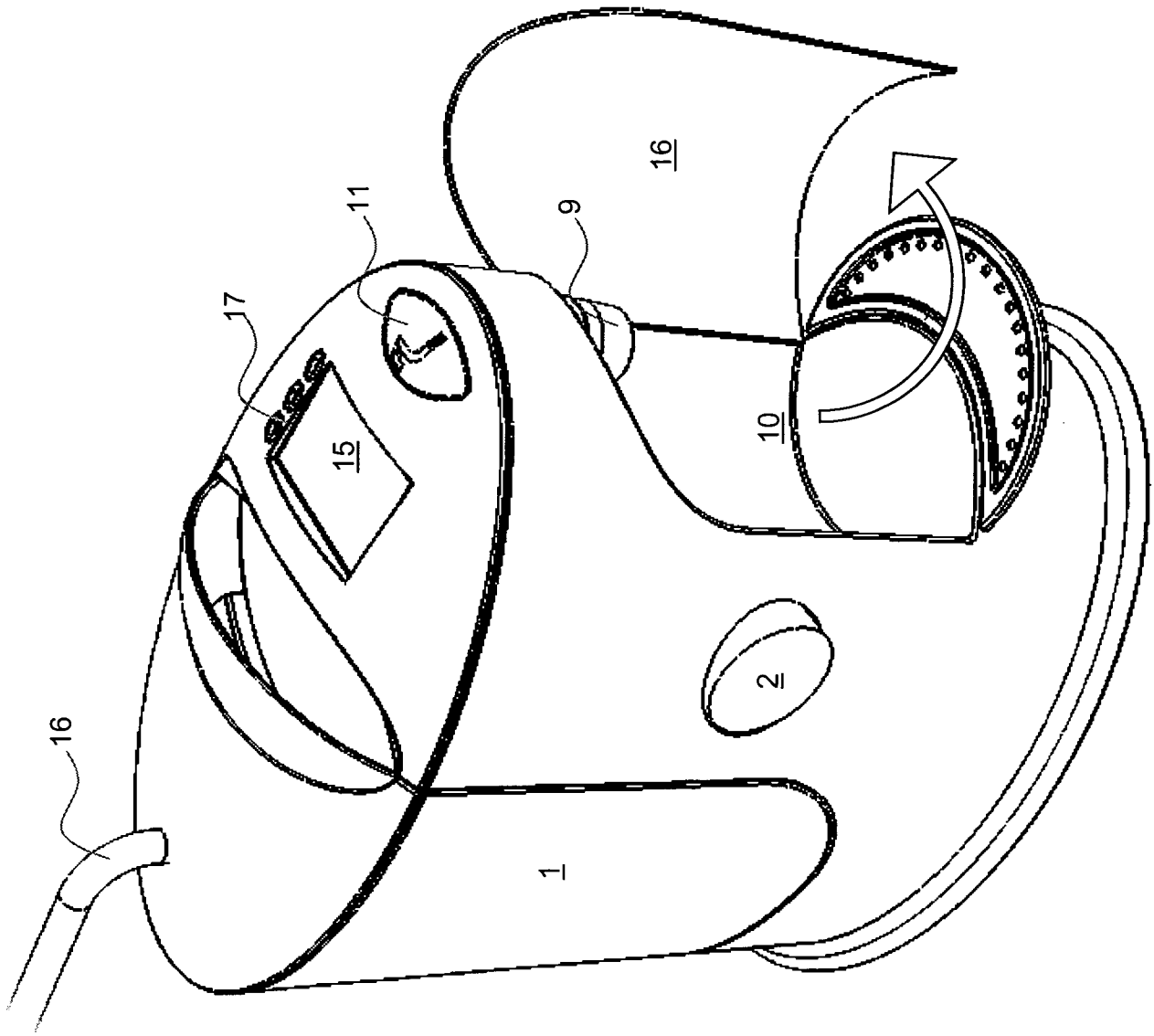


Fig. 5

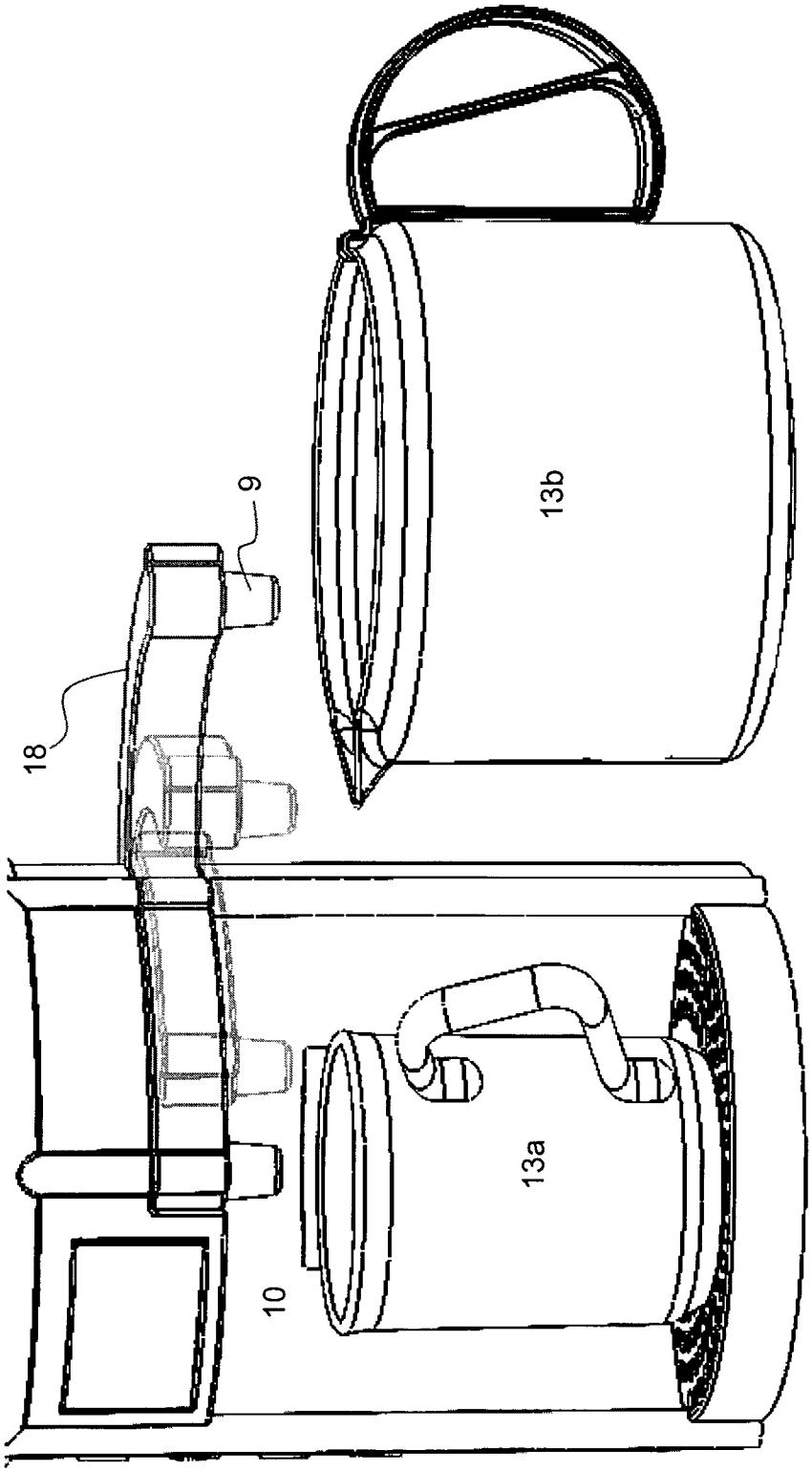


Fig. 6

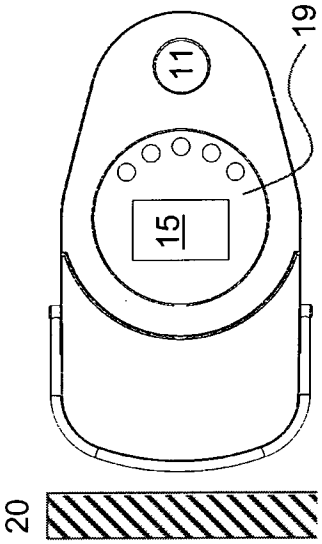


Fig. 7b

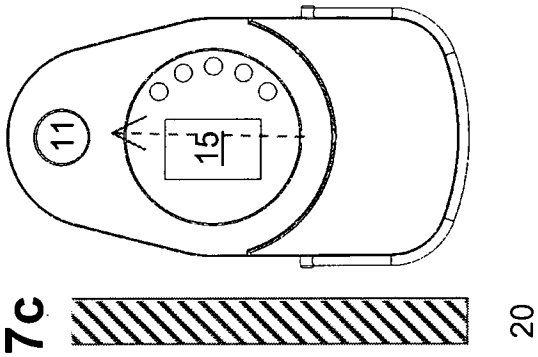


Fig. 7c

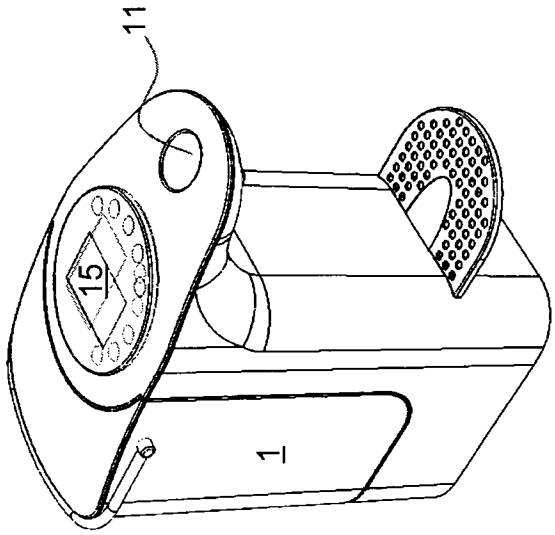


Fig. 7a

Fig. 8b

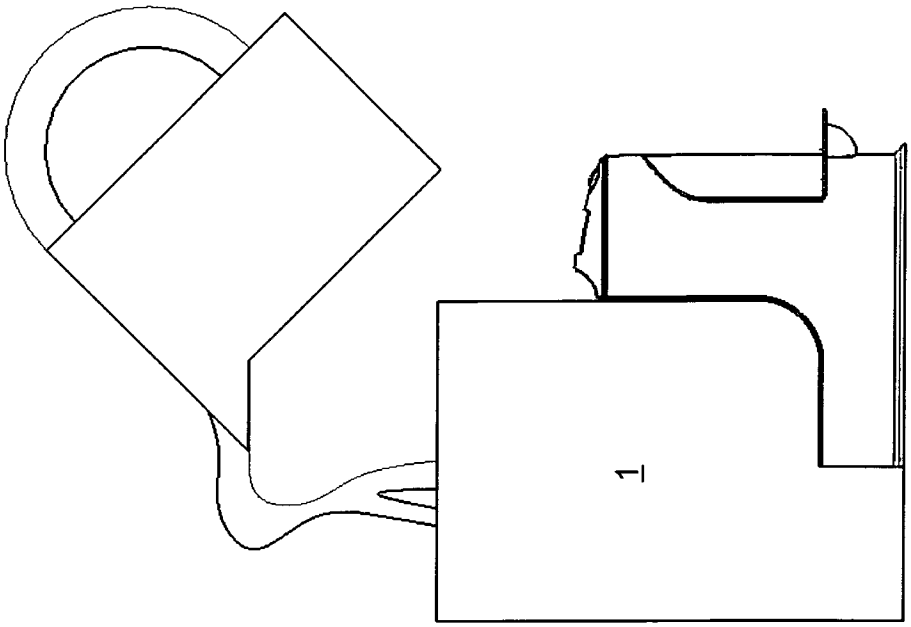


Fig. 8a

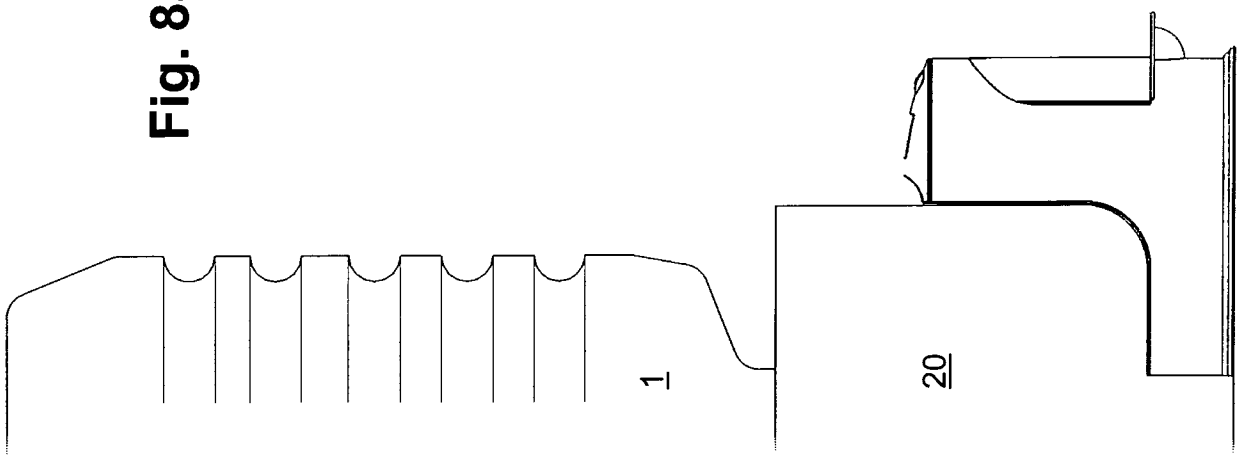


Fig. 9

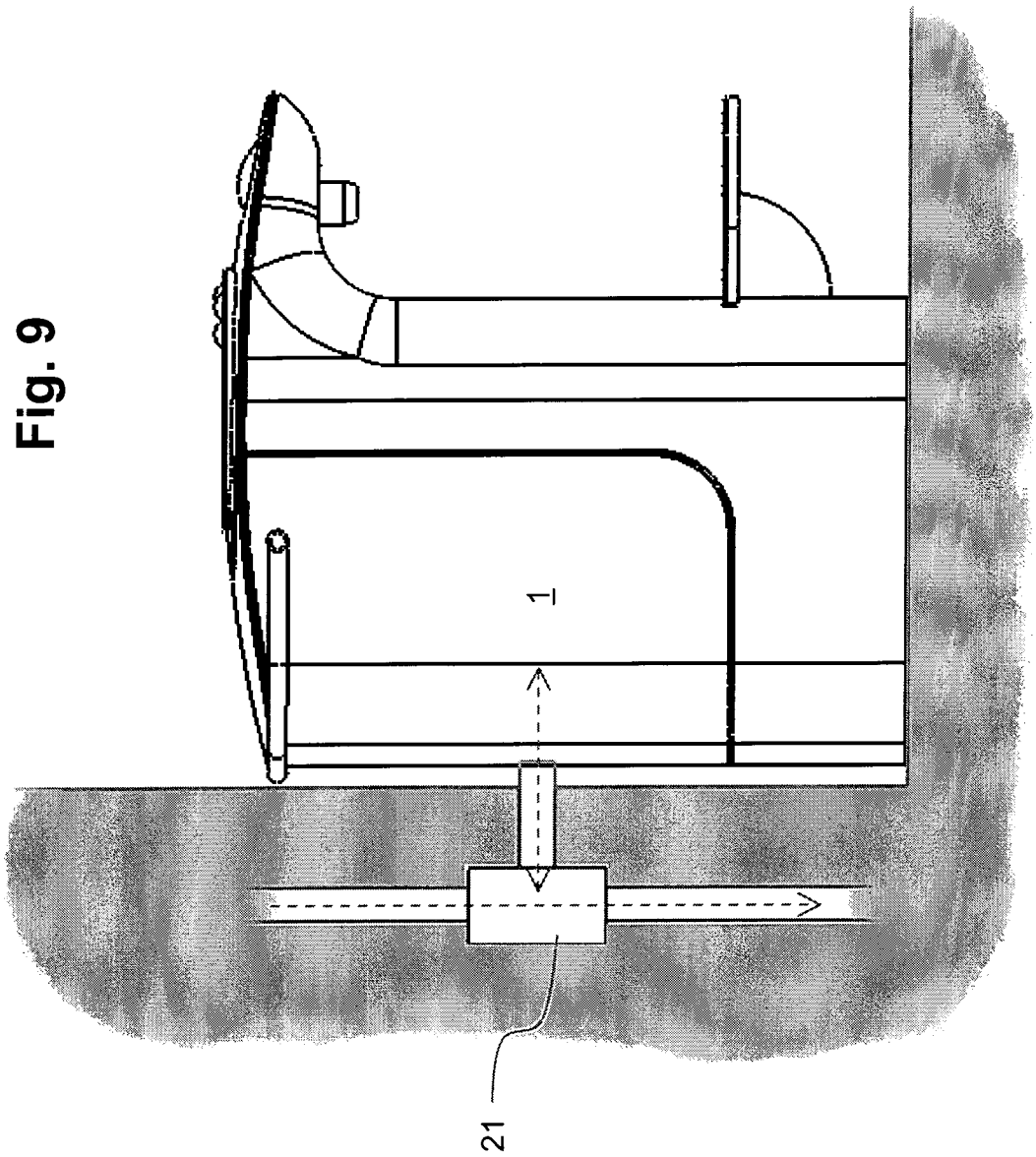
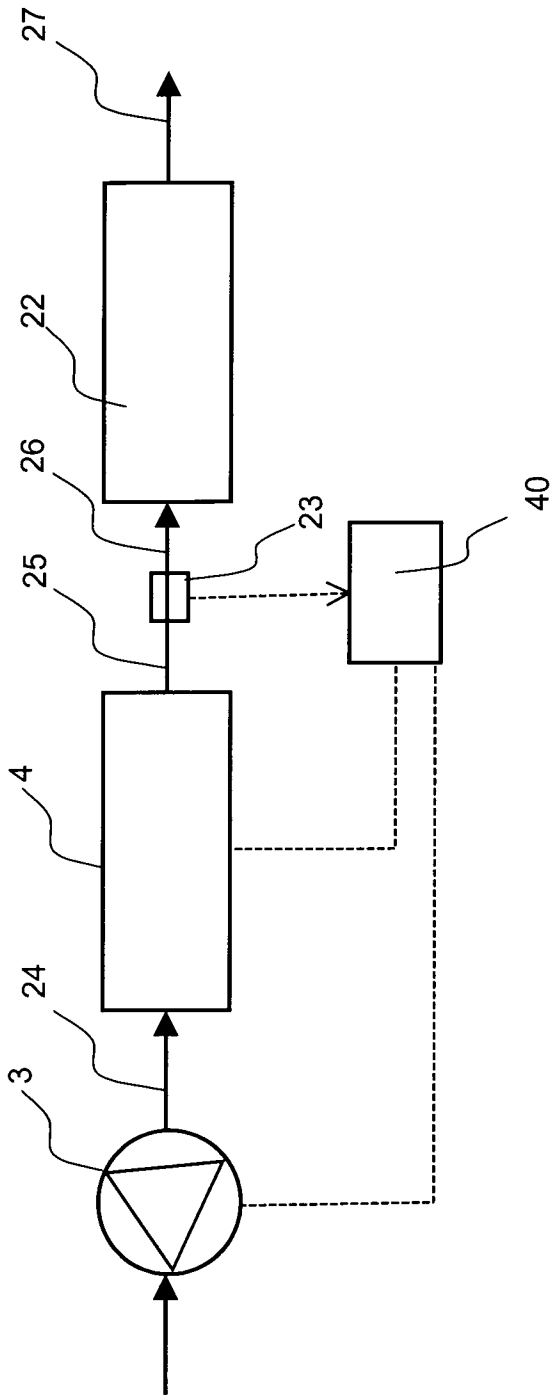


Fig. 10



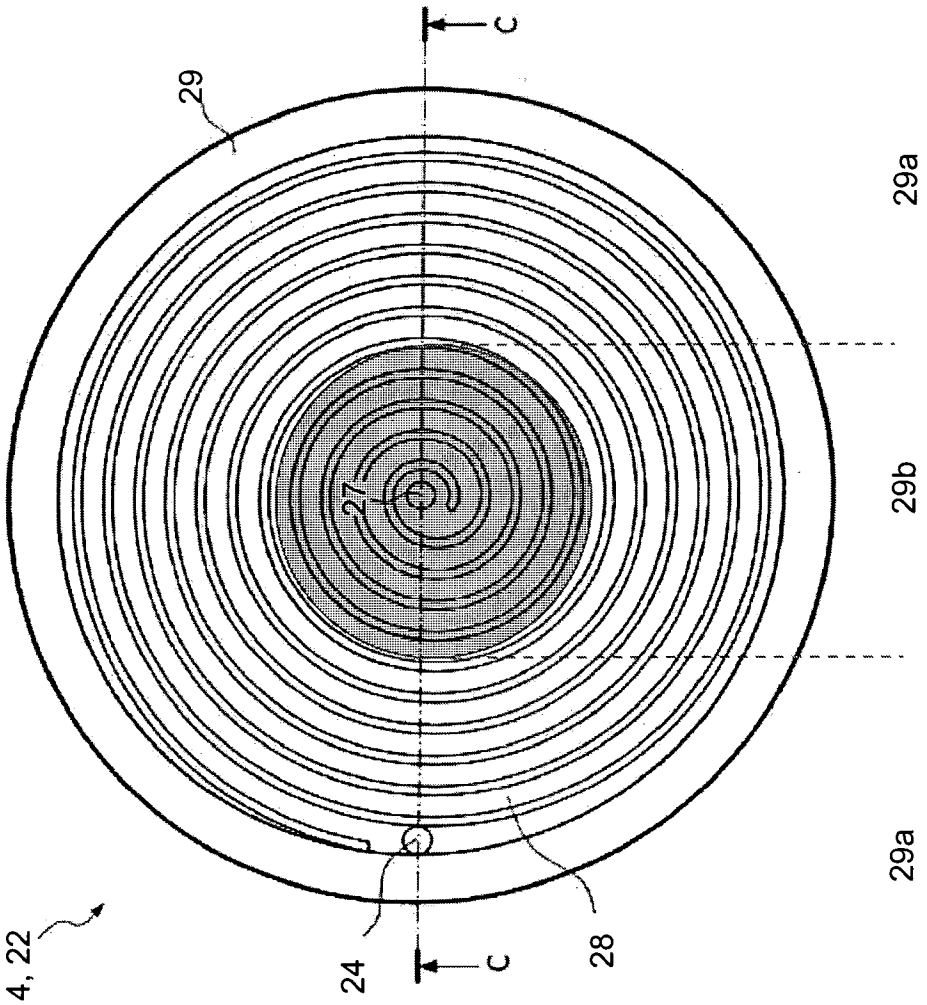


Fig. 11

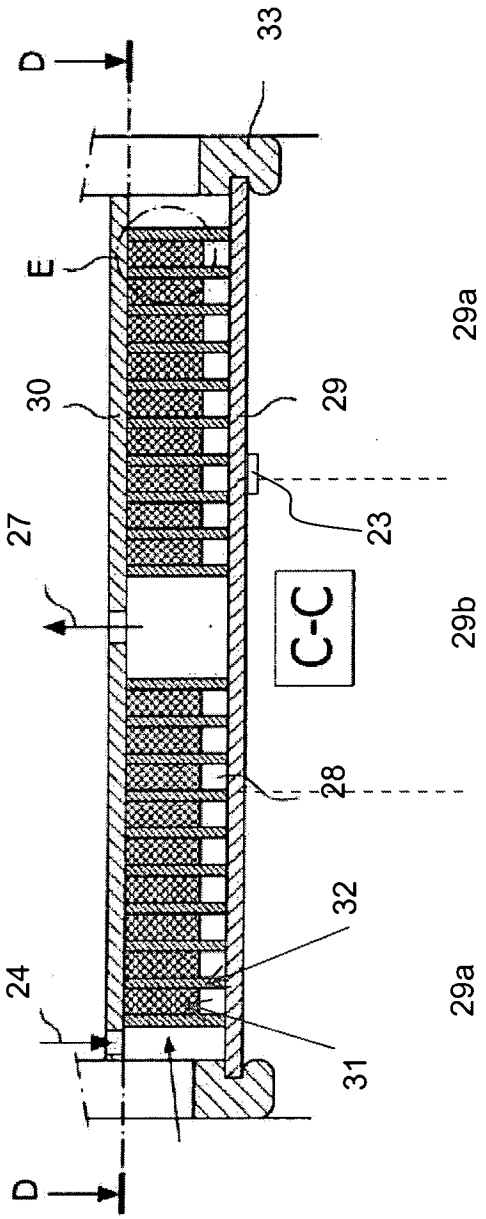


Fig. 12

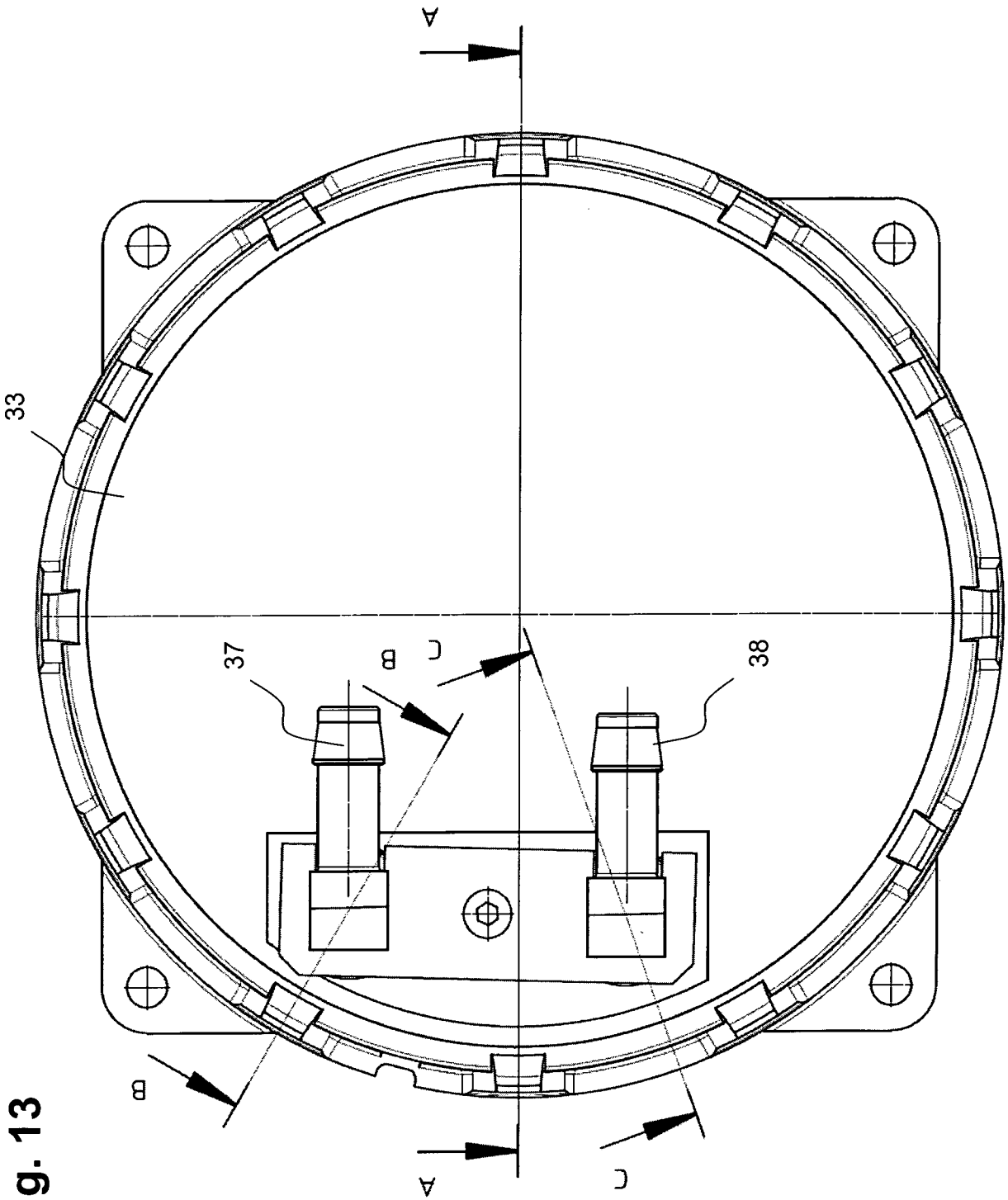


Fig. 13

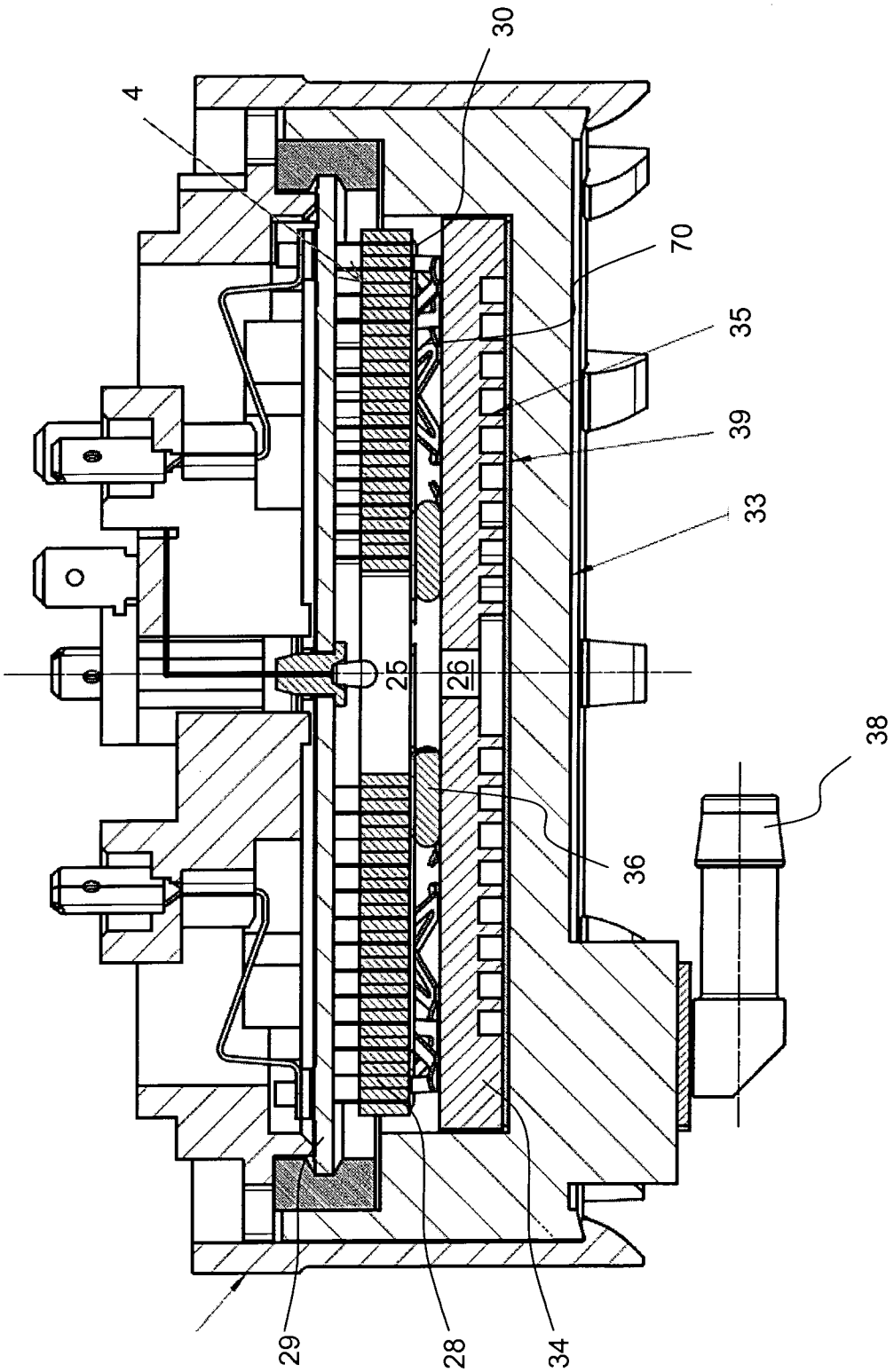


Fig. 14

Fig. 16

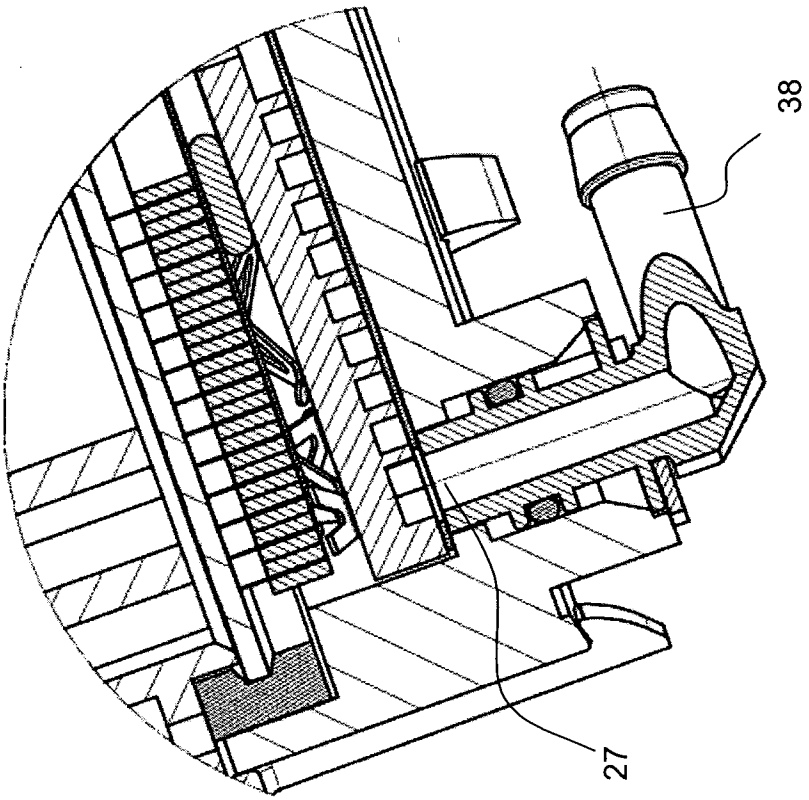
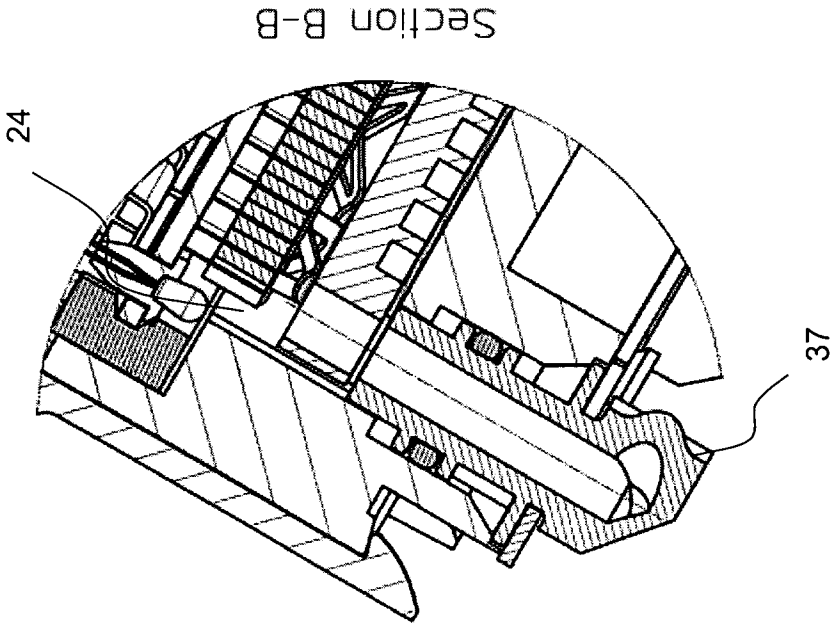


Fig. 15



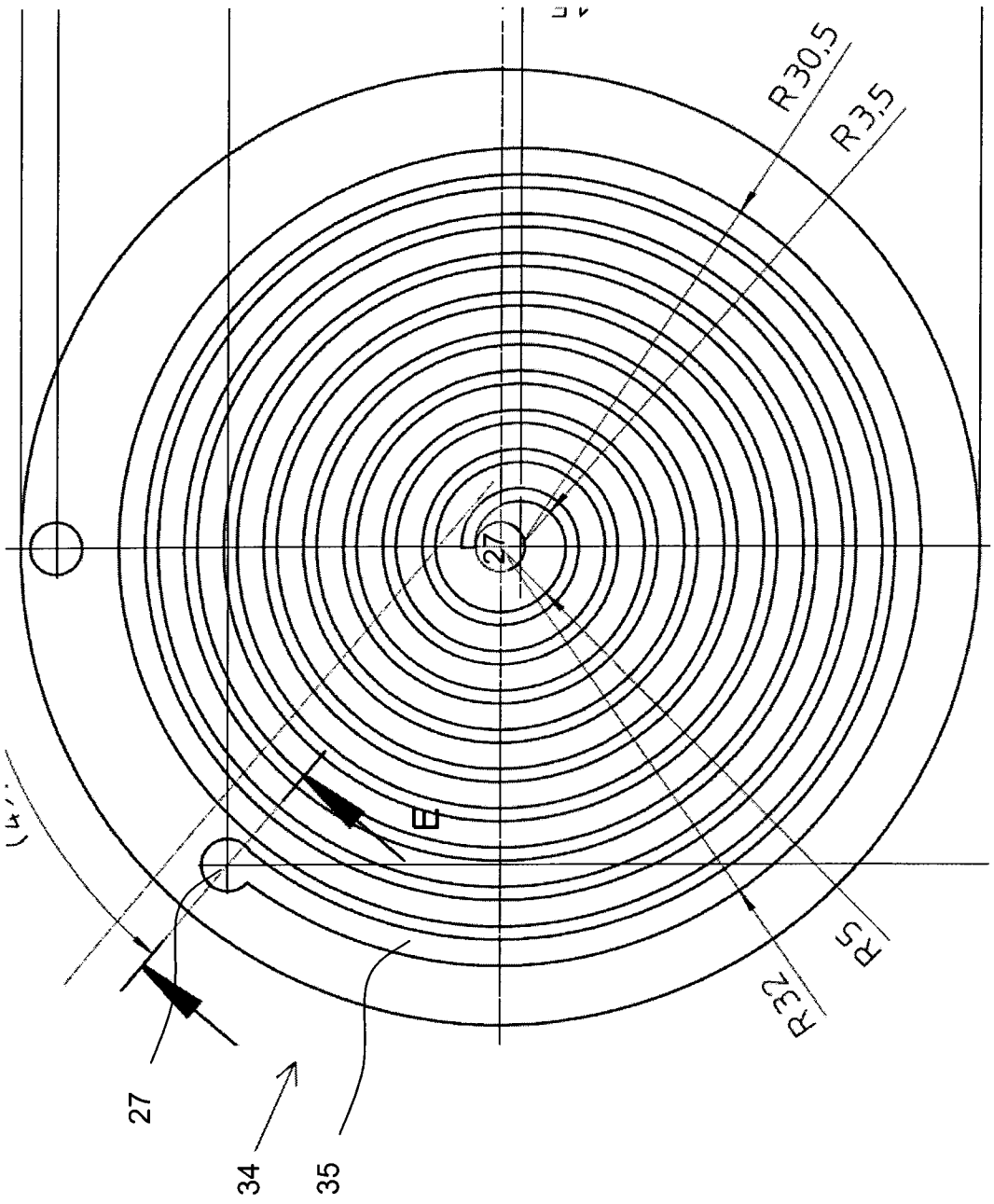


Fig. 17

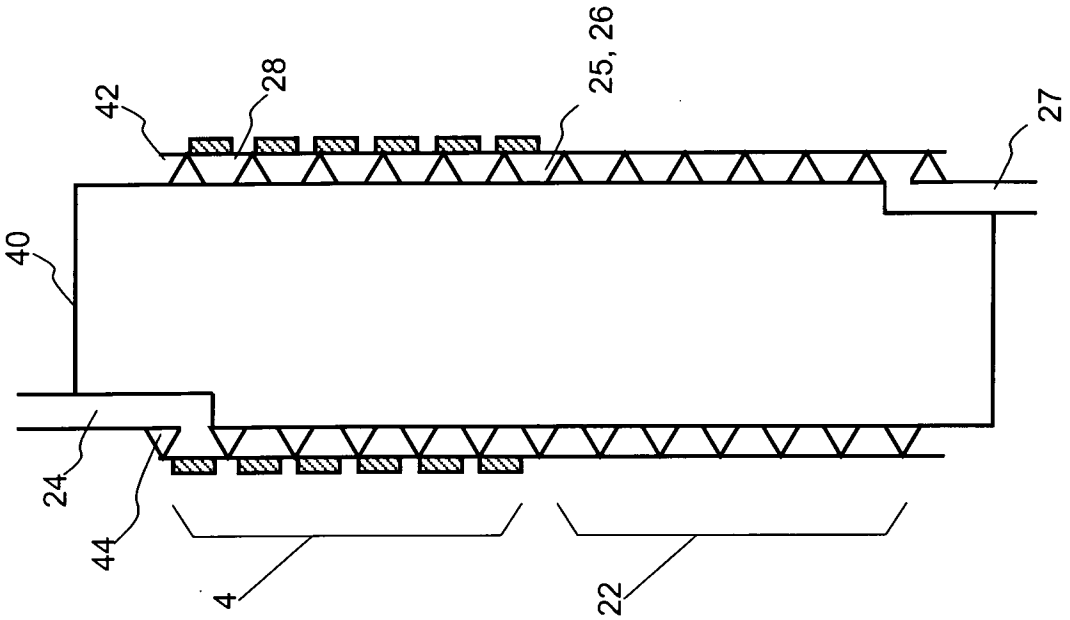


Fig. 18b

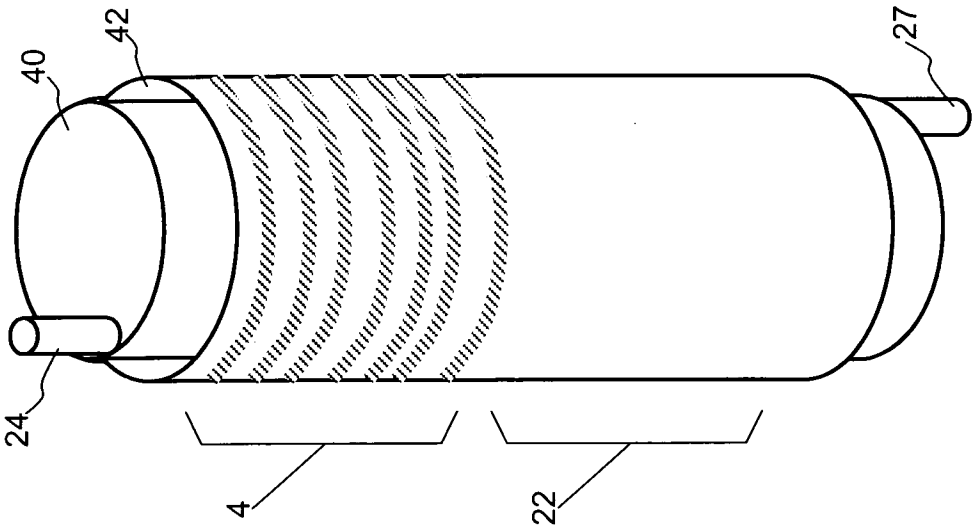


Fig. 18a

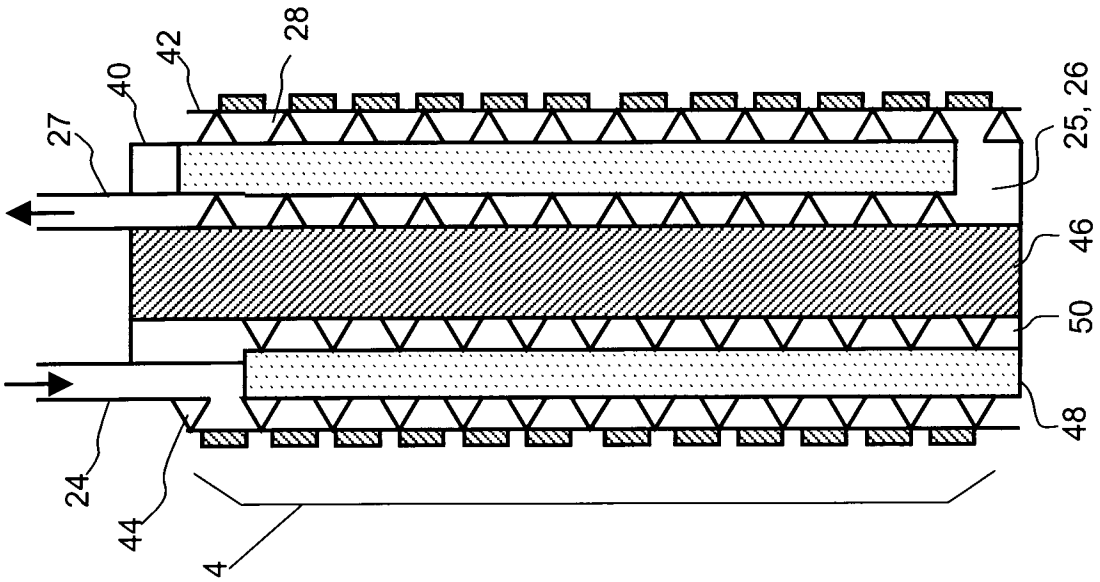


Fig. 19b

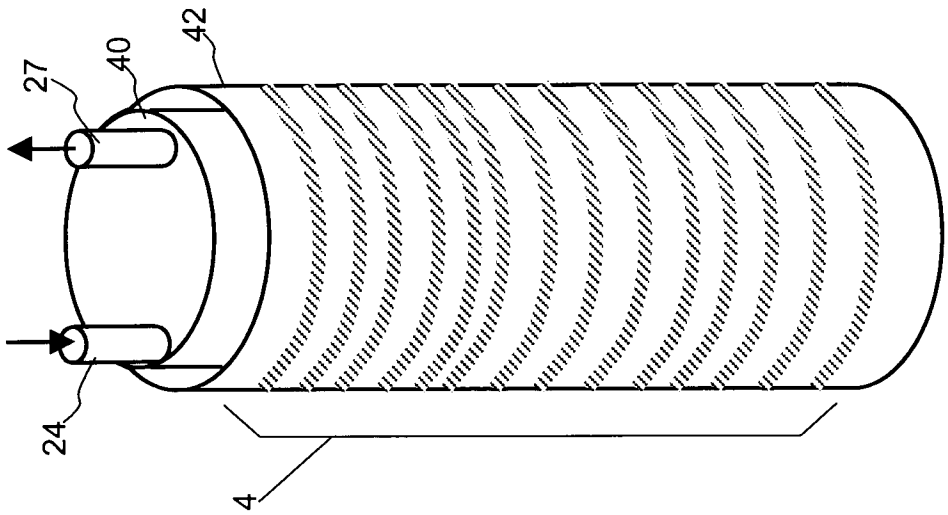


Fig. 19a

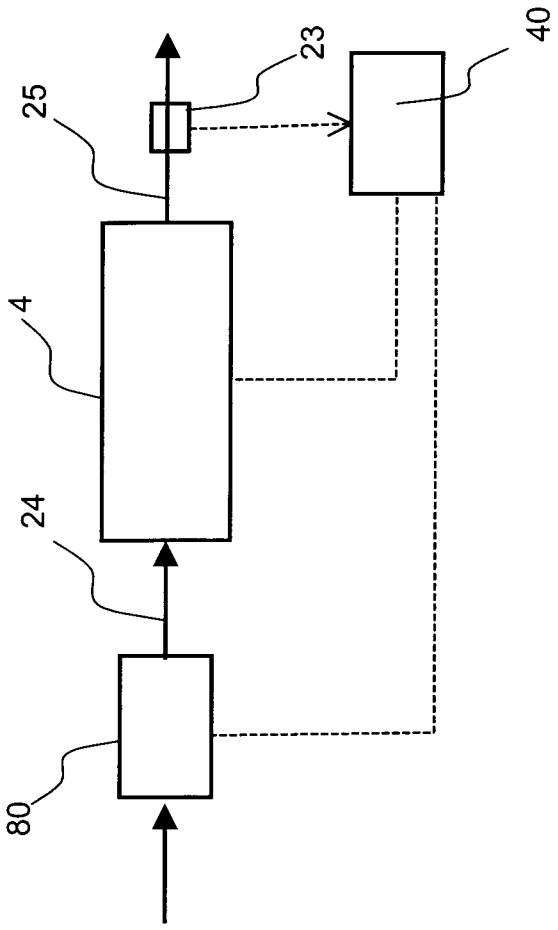


Fig. 20

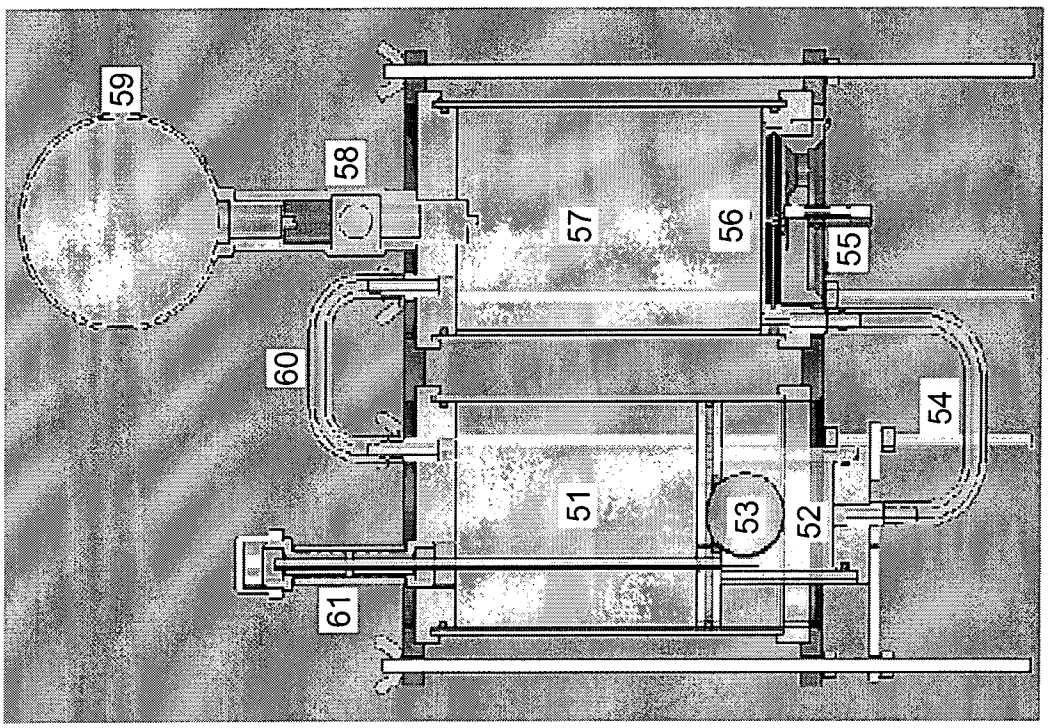


Fig. 21