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(54) Title: LIQUID HEATING VESSEL AND CONTROL

(57) Abstract:

Liquid Heating Vessel and Control

The present invention relates to electrically powered liquid heating vessels and to electronic controls therefor.

Background to the Invention

Electrically powered liquid heating vessels, such as kettles, typically include one or more controls such as a boil control for responding to a boil condition and a dry boil control for responding to an overheat condition where there is no liquid in the appliance. Typically, these controls are electromechanical and comprise one or more thermal actuators and switches. Electromechanical controls are cheap to manufacture and are generally reliable, but are limited in their functions.

Electronic controls, incorporating an electronic controller such as a microprocessor and one or more electrical or electronic sensors, have been proposed as an alternative to electromechanical controls. Early proposals include the applicant's own patent publications GB-A-2185161 and GB-A-2228634.

One problem to be addressed by electronic controls is boil detection. Electromechanical controls often include a steam tube for conveying steam from above the surface of the liquid to be heated into the control, where the steam can trigger a thermal actuator. However, this incurs a delay while steam collects above the surface of the liquid and travels down the steam tube to the thermal actuator. Furthermore, a significant 'head space' must be left above the liquid to allow the steam to collect, which leads to wasted space within the kettle that cannot be used to contain liquid. Moreover, steam is introduced into the control, which may lead to electrical problems.

Delayed boil detection is often undesirable, as it wastes energy and causes unnecessary condensation. Also, sufficient 'head space' is required to avoid the boiling liquid splashing out of the vessel, which is effectively wasted space within the appliance.

In many applications, it is only necessary to heat the liquid up to boiling, without actually boiling the liquid for any significant length of time. In other applications, for example where water quality is a problem, it may be desirable to boil the water for a prolonged period. In electrically heated cooking vessels, it would be desirable to have a 'simmer' setting whereby the liquid is maintained just at boiling point rather than being boiled vigorously. Another problem to be addressed by electronic controls is the setting of a target temperature below the boiling point of the liquid. One potential advantage of an electronic control is that the target temperature may be varied by the user. A sub-boil temperature may be detected by calibrating the sensor at boiling, and interpolating the sensor output to detect a predetermined sub-boil temperature. However, inaccuracies in calibration at boiling, caused for example by reduction in boiling point with reduced atmospheric pressure, will lead to inaccuracies in detection of a predetermined sub-boil temperature.

Additionally, it would be desirable for an electronic control to be able to determine accurately the level of liquid in the vessel.

Additionally, it would be desirable to be able to determine the temperature of the liquid, or to detect boiling or simmering, without requiring a thermistor or even without providing any temperature sensor within the vessel body.

Statement of the Invention

According to one aspect of the present invention, there is provided a method of detecting boiling or simmering in a liquid heating vessel, comprising detecting agitation or turbulence in the surface of the liquid and detecting boiling or simmering in response to said detected agitation or turbulence being characteristic of a simmering or boiling condition. Agitation or turbulence may be detected by detecting fluctuations in the level or angle of at least a part of the liquid surface. Fluctuations in the angle may be detected by emitting electromagnetic radiation towards said part of the surface and detecting fluctuations in reflection of the electromagnetic radiation from the surface.

According to another aspect of the present invention, there is provided a method of controlling boiling of liquid in an electrically powered liquid heating vessel, wherein the heating power level is adjusted after boiling to simmer the liquid.

According to another aspect of the present invention, there is provided a level sensor for a liquid heating vessel, comprising means for emitting a signal into the liquid, and for detecting the signal reflected from the surface of the liquid and thereby determining the level of the surface. The level may be determined by measuring the time taken for the emitted signal to reach the detector after reflection from the surface. Alternatively, the signal may be emitted at an oblique angle to the surface and the level may be determined by detecting the amplitude of the reflected signal. Alternatively, the frequency of the signal may be varied and a resonant frequency of the volume of liquid within the vessel detected, from which the level may be derived. The signal may be an electromagnetic signal, such as a light signal, or a vibration signal, such as an ultrasonic signal.

The ultrasonic signal may be emitted by a transducer. The ultrasonic transducer may comprise an element plate in the base of the vessel, and having a heating element disposed on the underside. An electrical signal at an ultrasonic frequency may be applied to a piezoelectric transducer on the underside of the element plate, or to the heating element itself; in the latter case, the interaction between the electrical signal and the earth's magnetic field may generate ultrasound within the liquid.

Ultrasonic vibration of the element plate may have other, independent advantages which are therefore described as independent aspects of the present invention below.

According to another aspect of the present invention, there is provided an element plate for a liquid heating vessel, including means for inducing ultrasonic vibration of the element plate. The ultrasonic vibration may inhibit the deposit of scale on the heating element, which also occurs during heating. Hence, the ultrasonic vibration may be induced during a heating operation.

According to another aspect of the present invention there is provided a method of detecting scale deposit on an element plate for a liquid heating vessel, comprising inducing ultrasonic vibration of the element plate at a nominal resonant frequency thereof, detecting the amplitude of the vibration, and determining the existence of scale deposit from the amplitude of the vibration.

Brief Description of the Drawings

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

Figure 1 is a schematic diagram of a liquid heating vessel in an embodiment of the invention.

Figure 2 is a plan view of a discrete component comprising an integrated cordless connector and power/switching board of an electronic control in an embodiment of the invention.

Figure 3 is a perspective view of the component of Figure 2 positioned in a base section of a kettle.

Figure 4 is a plan view of an element plate for connection to the component of Figure 2.

Figure 5 is a perspective view of the element plate installed in the base section, above the component of Figure 2.

Figure 6 is a vertical cross-section through the centre of the element plate, component and base section of Figure 5.

Figure 7 is a plan view of a user interface of the electronic control.

Figure 8 is a cut-away view of the user interface installed in the handle of a kettle.

Figures 9a to 9d are circuit diagrams of an electronic control according to an embodiment of the invention.

Figure 10 is a diagram of a level sensor using an ultrasonic transducer, in another embodiment of the invention.

Figure 11 is a diagram of a level sensor using a distance measuring device, in another embodiment.

Figure 12 is a diagram of a liquid heating vessel including a force sensor, in another embodiment of the invention.

Figure 13 is a diagram of an inductively heated liquid heating vessel including a force sensor, in another embodiment of the invention.

Figure 14 is a diagram of a liquid heating vessel including an optical boil detector, in another embodiment of the invention.

Figure 15 is a diagram of a liquid heating vessel including an optical boil detector, in another embodiment of the invention.

Figure 16 is a diagram of a liquid heating vessel including an optical boil detector, in another embodiment of the invention.

Figure 17 is a diagram of a liquid heating vessel including an optical boil detector, in another embodiment of the invention.

Figure 18 is a graph of voltage against time in an IR sensor in an embodiment of the invention.

Detailed Description of an Embodiment

Kettle Overview

Figure 1 shows schematically a jug kettle with an electronic control, as an example of a liquid heating vessel to which embodiments of the invention may be applied. In this example, the kettle is a cordless kettle comprising a vessel body 1 and a power base 2 having respective body and base cordless connectors 3 and 4, such as 360° cordless connectors of the type described in patent publication WO-A-94/06185 and/or as sold by Otter Controls Ltd. under the CS4/CS7 (power base socket) and CP7 (appliance plug) references. The power base is connectable by a power cord 13 to an electrical power outlet (not shown).

The vessel body 1 comprises a reservoir 5 for containing water to be heated, and a base section 6, as well as a spout 7, a lid 8 and a handle 9. Water is heated by an element plate 12 forming the base of the reservoir 5, and including a heating element on the underside (i.e. facing towards the base section 6). The element plate 12 may be fitted into the vessel body using the Easifix (RTM) fitting as described in WO 99/17645. The element may comprise a sheathed element and/or a thick film element. Preferably, the element plate is composed of stainless steel. Most preferably, the element plate is substantially as described in WO 06/83162. However, at least some embodiments of the present invention are applicable to a liquid heating vessels having an immersed heating element, rather than an element plate.

The base section contains an electronic control 10 for controlling the operation state of the vessel, as will be described in more detail below. A user interface 11 allows the user to operate the vessel, and may provide a display of the operational state of the vessel. The control electronics may be divided between the user interface 11 and the control 10 as desired.

A sensor 14 is arranged to sense the temperature of water in the reservoir 5 through the element plate 12, and is preferably thermally isolated from the heating element. In this example, there is no steam tube to carry steam from the top of the reservoir 5 to the control 10, since boiling is detected from the input of the temperature sensor 14 rather than by sensing steam, as will be described in more detail below. In some of the embodiments described below, boiling is detected by means other than temperature sensing, so that the sensor 14 is not required.

The vessel may have one or more additional features, some of which are described in more details below. However, to avoid repetition, some of these features will be outlined here.

Additional heating features of the vessel may include a 'keep warm' feature, in which the liquid is maintained around a predetermined temperature, preferably after boiling; this may be done by intermittent activation of the main heating element, or by intermittent or continuous activation of a secondary heating element. The predetermined temperature may be just below boiling point, or a lower temperature such as 80°C, and may be selectable by the user.

Another heating feature is a sub-boil feature, in which the liquid is heated up to a predetermined temperature below boiling, such as 80°C for making coffee, and the heating power is then switched off or reduced, for example to activate a keep warm mode. The predetermined temperature may be selectable by the user.

Another heating feature is a prolonged boil feature, whereby the liquid is heated to boiling and then boiled for at least a predetermined time, such as 30 seconds to 2 minutes, to sterilize the liquid.

Electronic Control Installation Details

Figures 2 to 8 show a specific embodiment of the control 10 in various stages of installation. Figure 2 shows a power supply and switching board 22 on which are mounted a capacitor 21 and relays 23 together with a control connector 27. The board 22 is mounted on a metal chassis 20, on which the cordless connector 3 is also mounted. In this way, the cordless connector 3 is integrated with the board 22 to provide an integrated component.

Figure 3 shows the chassis 20 inverted and mounted in the base section 6. The reverse side of the chassis 20 carries spring connectors comprising three power connectors 24, temperature sensor connectors 25 and an overheat sensor connector 26. As shown in Figure 4, the element plate 12 has corresponding power connection pads 24′, temperature sensor connection pads 25′, and overheat sensor connector 26′ which make electrical contact with the corresponding connectors when the element plate 12 is located on the chassis 20, as shown in Figures 5 and 6.

The element plate 12 also includes temperature sensor mounting pads 28 to which the temperature sensor 14 (shown in dotted outline in Figure 4) is connected. The temperature sensor 14 is located in a central portion of the element plate 12 which is free from thick film heating tracks, so that the sensed temperature is close to that of the water during heating, although there is some heat conduction from the surrounding heating tracks to the sensor 14 via the element plate 12. The element plate 12 preferably comprises a stainless steel substrate and an insulating layer on which the heating tracks are deposited. The temperature sensor 14 preferably comprises an NTC thermistor.

The element plate 12 comprises a high power heating track 29 and a low power heating track 30, which are independently switchable via separate high and low power connection pads 24′. At 240 VAC, the high power track 29 is rated at 2073 W and the low power track at 1027W, giving a maximum power of 3.1 kW when both tracks are powered in parallel.

The overheat sensor connector 26′ is used to detect leakage current which is indicative of an overheat condition of the element plate 12, as described in WO 06/83162. Hence, the control 10 can detect a dry boil condition and/or scale deposit.

Figure 7 shows the user interface 11 in this embodiment, which is connectable to the control connector 27 on the power and switching board 22 by a control cable 32. The user interface portion comprises user actuable buttons 34, and an LCD display 36, as well as a lighting connector 38 and an audio connector 40. As shown in Figure 8, the user interface 11 may be provided in the handle 9 so that the display 36 and buttons 4 are easily accessible to the user.

The user interface 11 includes a microprocessor arranged to control operation of the vessel by means of the power and switching board 22, in response to user control by means of the buttons 34. The microprocessor also controls the display 36, as well as lighting effects via the lighting connector 38 and audio via the audio connector.

The user interface 11 may be movably mounted so that its position or configuration can be altered to suit the user. For example, the display 36 may be pivotable and/or rotatable so that it is more easily visible when the vessel body 1 is separated from or connected to the base 2. The display 36 may be pivotable about a substantially vertical axis and mounted on the lid or upper surface of the vessel, so as to be configurable for left or right-handed operation.

Electronic Control Circuit Diagram

Figure 9a is a circuit diagram of the power supply and switching board 22, showing the connection of the relays 23 to the power connectors 24. The capacitor 21 forms part of a power supply that supplies a low DC voltage on the control connector 37 from the mains AC power.

Figure 9b is a circuit diagram of an interface circuit for providing the voltages necessary to drive the relays 23 and the lighting connector 38. This interface circuit forms part of the user interface 11, although it could alternatively be located within the base section 6.

Figure 9c is a circuit diagram of the connection of the microprocessor to the temperature sensor and overheat sensor inputs. The diagram also shows the connection of the user actuable buttons 34. Figure 9d is a circuit diagram of the LCD driver circuit for driving the LCD display 36.

The microprocessor includes a program memory in which one or more control programs are stored for performing one or more control functions, as described below. The control program may be stored in program memory during manufacture. In one embodiment, the control program is stored in flash memory and may be updated via an interface to the microprocessor and/or the program memory. The interface may be an external interface such as a USB port, to allow programs and/or data to be transferred to the control. The external interface may be a wireless interface, such as a Bluetooth (RTM) interface.

The control is arranged so that the high-voltage circuits, such as the power supply and the relays, are formed within the base section, close to the element plate 12 and the cordless connector 3. Conversely, the low voltage electronic circuits form part of the user interface section, which is remote from the element plate 12. The low voltage electronic circuits are more susceptible to heat and moisture, so it is advantageous to locate them away from the base section 6.

In an alternative embodiment, at least the power switching components of the control are located in the power base 2 and are controlled via the cordless connectors 3, 4. For example, the control may send a low voltage pulse on the earth pin of the cordless connector 3, which controls the switch to toggle the power. In this way, signalling between the vessel body 1 and the cordless base 2 may be simplified. As another advantage, the power switching components are further removed from the control logic, so that the risk of interference is reduced.

In an alternative embodiment, data and/or signals may be communicated between the body 1 and the base 2 wirelessly, for example via infra-red, optical or RF signalling. In the case of infrared or optical signalling, one of the body 1 and/or the base 2 may include a circular light guide 2a concentric with the cordless connector, with a corresponding infrared transmitter and/or receiver 1a at the same radius, as shown schematically in Figure 10, so that communication may occur regardless of the relative orientation of the body 1 on the base 2.

In an alternative embodiment, the power supply for converting mains voltage to a lower DC voltage is provided in the power base 2 and the cordless connectors 3, 4 provide power connections both for mains voltage and the lower DC voltage. The lower DC voltage may be connected via additional terminals in the cordless connectors, such as disclosed in our UK patent no. 2228634. For example, there may be five terminals: live and neutral for each of the mains voltage and low voltage, and an earth terminal.

Auxiliary Power Supply

A power source, such as a battery or capacitor, may be provided in the vessel body 1 to provide power to the electronic circuits when the vessel body 1 is removed from the power base 2. Preferably, the power source is rechargeable and is recharged when the vessel body 1 is connected to the power base 2. Additionally or alternatively, the power source may be charged when the vessel body is not connected to the power base 2, for example by a photovoltaic panel on the vessel body 1. Alternatively, the power source may be non-rechargeable, such as a non-rechargeable battery.

The power source may preserve the state of at least some parts of the electronic control 10, and may be sufficient to power lighting or other effects as described below. Preferably, the user may operate the user interface 11 while the vessel body 1 is removed from the power base, for example to change settings such as control settings and/or lighting. The user interface 11 may be operable in a demonstration mode, to demonstrate non-heating features of the vessel when the vessel is not plugged into the mains. In that case, the vessel should preferably be chargeable without a mains connection, such as by means of a photovoltaic panel, or the power source should be renewable.

Standby Mode

To save power, the electronic control 10 may enter a standby mode when the vessel body 1 is separated from the base 2 for more than a predetermined interval. In standby mode, the power drain may be reduced by switching off lighting and/or disabling features of the user interface 11. The vessel body 1 may leave standby mode in response to being reconnected to the base 2 and/or in response to user control via the user interface and/or in response to other inputs, such as from a user proximity sensor.

Alternatively or additionally, when the vessel body 1 is separated from the base 2 the electronic control 10 may enter a mode that is not a low power mode, but is intended to encourage the user to replace the vessel body 1 on the base 2. For example, the control 10 may detect the charging level of the power source within the vessel body 1, and issue an alert to the user when the charging level is below a predetermined level. Alternatively, the control 10 may alert the user when the vessel body 1 has been separated from the base 2 for more than a predetermined interval, to ensure that the vessel body 1 is not misplaced or unavailable when the user next wants to use the vessel.

Override Mode

Mechanical sensors such as snap-acting bimetals are generally arranged to reset quickly after activation; for example, a bimetal used as a dry boil sensor is typically arranged to be in good thermal contact with an element plate until activated, at which point the bimetal snaps out of contact with the element plate, and is therefore able to cool down and reset quickly. A bimetal used as a steam sensor may be arranged in a steam chamber or adjacent the outlet of a steam tube. When the steam sensor is activated, steam is no longer generated and so the quantity of steam around the sensor decreases rapidly; the sensor therefore cools and resets quickly.

In some embodiments of the invention, the sensor 14 is an electrical or electronic sensor and does not move out of thermal contact with the element plate 12 when the target temperature or dry boil condition is detected. Hence, the sensed temperature remains high for some time after power to the element plate 12 is switched off or reduced, due to the thermal inertia of the element plate 12, unlike the rapid cooling of mechanical sensors.

In some cases, it is desirable to allow the user to reactivate power to the appliance, for example to force reboiling of liquid in the reservoir 5, when the sensed temperature is still above a target temperature. The control 10 enters an override mode in response to user actuation to reheat the liquid when the sensed temperature is still above the target temperature. In the override mode, the control 10 switches on or increases heating power for a predetermined time, such as 10 seconds, and then switches off or reduces power. The override mode also has the benefit of reassuring the user that the vessel is still operational; otherwise, a user accustomed to the rapid resetting of manual sensors may assume incorrectly that the vessel is faulty.

Volume/Level Detection

The volume or level of water in the reservoir 5 may be detected by means, as described below. In one embodiment, as shown in Figure 10, the liquid level is sensed by an ultrasonic transducer 48 coupled to the element plate 12. Ultrasonic pulses are reflected off the surface of the liquid and are detected by the transducer 48. The control 10 measures the time taken for the pulses to be reflected off the surface and thereby calculates the distance of the surface from the element plate 12 and therefore the liquid level. Alternatively, the transducer 48 could be located above the surface of the water, such as in or adjacent to the lid 8, and the level of the surface thereby determined and used to calculate the liquid level.

In an alternative embodiment, the control 10 varies the frequency of the ultrasonic transducer and determines the amplitude of the reflected signal at the different frequencies and hence a resonant frequency or frequencies. The reflection of the ultrasound between the element plate 12 and the surface will determine a resonant frequency in the liquid having a wavelength that is a function of the distance between the surface and the element plate. The speed of sound in water is approximately 1500 m/s, therefore a frequency above 20 kHz will give a wavelength of 7.5 cm, which is comparable to the depth of water in a kettle. The control 10 therefore derives the liquid level from the resonant frequency or frequencies.

The resonant frequency may alternatively be a resonant frequency of part or all of the vessel body 1, such as the resonant frequency of the walls. The amplitude of the resonance will be damped according to the volume of water in the vessel. Hence in an alternative embodiment the frequency of the ultrasound is fixed, and the amplitude of the resonance is detected to determine the water level or volume. As an alternative to the ultrasonic transducer, an electrical signal at an ultrasonic frequency may be passed through the heating element itself, or through a separate track on the element plate; the electrical signal interacts with the earth's magnetic field to cause ultrasonic vibrations within the element plate. It has been observed that passing 50 Hz mains current through a thick film element can cause audible vibration of an element plate; this effect, which is normally considered as a nuisance to be avoided, is harnessed in the present embodiment by the use of ultrasonic signals.

As an alternative to the ultrasonic signal, an electromagnetic signal such as a light signal may be used; the light may be laser light. The electromagnetic signal may be emitted as a short pulse, or series of pulses, which is reflected off the surface of the liquid and detected by a photodetector. The time of flight may be measured using conventional components such are used in laser distance meters, and used to calculate the liquid level.

In one embodiment, as shown in Figure 11, a distance-measuring device 48 is situated at or around the top of the reservoir 5. The device may be a laser or ultrasonic distance measuring device. The distance-measuring device 48 may be positioned substantially on the central vertical axis of the reservoir 5, so that the accuracy of the water level accuracy measurement is not dependent upon the vessel body 1 being vertical. Alternatively, there may be provided a plurality of distance measuring devices at different positions, to compensate for the angle of the vessel body 1. The distance measuring device(s) may be used to accurately measure the level of water during filling at the tap, when the vessel body 1 is likely to held at an angle. Alternatively, the distance-measuring device may be positioned outside the water reservoir of the vessel, and may be directed at the water surface through a window.

As an alternative to being pulsed, the signal may be substantially continuous but modulated to provide a timing reference. Alternatively, the signal may be pulse modulated.

Alternatively, electromagnetic radiation or ultrasonic vibration may be directed obliquely at the surface of the liquid, and a detector is positioned to detect the radiation or vibration reflected off the surface. At the liquid level changes, the amplitude of the detected radiation or vibration changes, and the level is detected therefrom.

Weight/Force Sensing

In another embodiment, as shown in Figure 12, the volume of liquid in the reservoir 5 is detected by weighing the reservoir, for example using a force sensor 51 in the body 1 or in the base 2. The force sensor 51 may comprise a strain gauge or other electrical, electronic or optical force detecting component arranged to measure the force between the body 1 and the base 2. The force sensor is calibrated to compensate for the weight of the body 1; since the liquid has a known density, the volume of liquid is proportional to the measured weight.

Additionally or alternatively, the force sensor 51 may be used to detect whether the body 1 is on the base 2, by determining whether the detected force is less than the calibrated weight of the body 1. For this function alone, an accurate force sensor is not required, but a pressure switch or light sensor may be used instead. The light sensor may be provided in the base 2, and be arranged to be occluded when the body 1 is located on the base 2.

Additionally or alternatively, the force sensor may be used to detect whether a user is touching the body 1, by detecting the resultant change in force between the body 1 and the power base 2. Hence, the force sensor 51 may be used as part of a touch sensitive user control.

Additionally or alternatively, the force sensor may be used to detect agitation of the liquid within the reservoir 5, caused by simmering and/or boiling of the liquid. The agitation causes small characteristic fluctuations in the force between the vessel body 1 and the power base 2, which may be sensed by the force sensor 51 and used by the control 10 to detect simmering and/or boiling.

The use of a force sensor 51 for boil detection may provide a particularly advantageous arrangement in which the number of electrical components within the vessel body 1 is reduced to a minimum. For example, the switching and control functions may be located in the power base 2 and/or an intermediate module 11a, if present. Boil sensing may be provided by a force sensor located within the power base 2. Hence, the electrical components within vessel body 1 need only comprise the element plate 12 and the cordless connector 3, and a dry boil protector if required by safety standards. The cordless connector 3 may be a washproof cordless connector as described for example in WO08/012506A1, so that the vessel body is washable in a dishwasher, and is particular suitable for heating liquids other than water.

In a further advantageous embodiment as shown in Figure 13, the vessel body is heated inductively by an induction heater 52 located within the power base 2, and boiling of the liquid is sensed by a force sensor 51 arranged within the power base and arranged to sense the force applied by the vessel body 1 onto the base 2. In this case, there is no need for any electrical components in the vessel body 1, only an inductively heatable portion such as a plate 12 forming at least part of the bottom of the reservoir 5. The construction of the vessel body 1 is greatly simplified and the vessel body can be made fully washproof without the need for electrical sealing systems. A user interface 11 may be provided in the base 2, or as a remote control.

Dry boil protection may be provided by selection of the material and/or structure of the inductively heatable portion so as to provide a Curie temperature above the normal temperature of the inductively heatable portion during heating, but below the point at which dry boiling would cause damage to the vessel body. Thus, dry boil protection may be provided by self-regulation of the temperature of the inductively heatable material. As an alternative, dry boiling may be sensed in the power base by detecting a change in the inductive coupling between the inductive heater and the inductively heatable material, caused by a rise in temperature of the latter.

In liquid heating vessels that do not include a cordless power base 2, the force sensor may be provided in the vessel body 1 and be arranged to detect the force between the body 1 and a surface on which the body 1 rests.

Ultrasonic Scale Inhibition

Ultrasonic vibration may be induced in the element plate 12, for example using an ultrasonic transducer 48 as described above, for purposes other than level sensing. For example, ultrasonic vibration may inhibit the formation of scale on the element plate 12, which also tends to occur during heating. This effect is similar to that used in ultrasonic cleaning devices; the ultrasonic vibration loosens particles of scale deposited on the element plate 12. Hence, ultrasonic vibration may be induced in the element plate 12 during or after heating, either continuously or intermittently.

The use of ultrasonic vibration to inhibit scale formation is particularly advantageous in an embodiment wherein the element plate 12 includes a noise reduction coating or treatment on the liquid-facing side, as described for example in the patent application PCT/GB07/004797 or patent publications EP-A-1859711 or GB-A-2386532.

The noise reduction coating may be a resin-based coating having one or more of polyethersulphone (PES), polyphenylenesulphide (PPS), polyethylene terephthalate (PET), and polyamide/imide (PAI). The coating additionally comprises a non-stick or hydrophobic component, such as a fluoropolymer. The fluoropolymer may comprise one or more of polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), and perfluoroalkoxy (PFA).

The coating may further comprise one or more fillers or pigments, such as aluminium, barium sulphate, barytes, carbon black, chlorite, copper chrome spinel black, glass, iron oxide, mica, quartz, silica, talc and titanium dioxide. The coating may further comprise a flow additive such as acrylate resin.

In one preferred embodiment, the composition of the dry coating (e.g. after firing) includes 50-65% resin component and 10-20% non-stick component. Preferably, the resin component comprises PAI. Preferably, the non-stick component comprises PTFE. One particularly preferred coating is a Greblon™ coating available from Weilburger Coatings GmbH, particularly a Greblon 1215 coating comprising PAI and PTFE with fillers and a flow additive, or a variant known as 'Ultra Serene' (TM).

The treatment may comprise a roughening treatment. In one example, the surface is roughened with a finish of 0.5 - 4 Ra (average surface roughness), but most preferably approximately 2 Ra. The surface may be abraded, roughened (e.g. by grit blasting), scoured (e.g. with Scotchbrite™), surface etched and/or blast finished.

It has been observed that use of such a coating or treatment in hard water areas may cause a high-pitched squealing or whistling noise after a few heating cycles, caused by build-up of scale on the surface coating or treatment. Advantageously in the present embodiment ultrasonic vibration is applied to the element plate 12 during or after heating, to inhibit scale build-up and the consequential high-pitched noise, without the need for a complex disruptor structure such as disclosed in EP-A-1859711.

The ultrasonic transducer 48 may generate ultrasound in a frequency range of 40 kHz to 1.6 MHz, and may have a power consumption from a few milliwatts to 50 W. The transducer 48 may be coupled directly to the element plate 12 and/or coupled via liquid in the reservoir 5; for example, the transducer 48 may be coupled on an outer surface of the reservoir 5 such that ultrasound is emitted through a wall into the reservoir 5. This arrangement has an advantage of thermally insulating the transducer from the element plate 12.

Ultrasonic Scale Detection

Scale deposit on the element plate 12 may alter the resonant properties of the element plate, and may in particular damp the resonance or alter the resonant frequency of the element plate. Hence, the control 10 may detect scale deposit on the element plate 12 by inducing ultrasonic vibration of the element plate at a nominal resonant frequency thereof, detecting the amplitude of the vibration, and determining the existence of scale deposit from the amplitude of the vibration. Reduced amplitude at the resonant frequency may indicate damping and/or a shift in resonant frequency and therefore the presence of scale on the element plate.

Efficiency Rating

At least some of the level sensors or sensing techniques described above may be used to detect the level or volume of liquid remaining in a liquid heating vessel after the liquid has been heated, some of the liquid has been dispensed, and the vessel is returned to its normal position, such as a kettle being returned to its cordless connector base. The liquid remaining in the vessel after heating and dispensing may indicate that the liquid heating vessel is not being used efficiently, as it was filled with more liquid than was needed.

Hence, in a further embodiment of the invention, the control measures the quantity of water heated during a heating operation, and the quantity of water remaining after the vessel body 1 is returned to the power base 2, for example following a dispensing operation. The ratio of remaining water to heated water is calculated and used to determine an efficiency rating which is indicated to the user as a measure of how efficiently the vessel is being used. This indication may be made every time the vessel body 1 is returned to its power base 2, or only if the efficiency rating is low i.e. the ratio of remaining water to heated water is high. The control may calculate an average efficiency rating, for example based on the average ratio of remaining water to heated water over the last 10 operations, or some other number of operations.

Boil Detection by Resistance

In an alternative embodiment, boiling is detected by measuring the resistance of water in the reservoir 5. This may be done by measuring the resistance between electrodes in contact with the water; preferably, the element plate 12 forms one of the electrodes, while the other electrode is positioned in a side wall of the reservoir, below the minimum safe water level. Localised boiling may occur on the element plate 12 before the boiling point is reached. As the boiling point is approached, steam bubbles forming on the element plate 12 become larger and increase the resistance of the water as measured between the element plate 12 and the other electrode. The control program measures this resistance, and detects boiling when the resistance has increased by a predetermined percentage of its initial value, or the resistance increases at above a predetermined rate.

If the electrical resistance is very high because the electrode in the side wall is not immersed, the control program may determine that there is insufficient water in the vessel, and may inhibit heating.

Boil/Simmer Detection by Agitation/Turbulence

In one embodiment, the agitation is monitored by a water level detector that is sensitive to small, rapid fluctuations of the water level as the water becomes agitated. One such level detector is the laser or acoustic level detector illustrated in Figures 10 and 11. The detector accurately measures fluctuations in the absolute distance to the water surface, and the control 10 detects when the fluctuations exceed a predetermined level to determine when boiling or simmering occurs. The predetermined level may vary dependent upon the amount of water in the vessel, which may also be determined by the device according to the absolute distance to the water surface.

In another embodiment, the agitation is monitored by an acoustic sensor that detects the characteristic sound of water reaching boiling point, such as the reduction in heating noise caused by a reduction in the collapse of steam bubbles within the water as the water reaches boiling.

In another embodiment, a capacitance sensor is used to detect the small, rapid fluctuations in the water level.

Alternatively, boiling and/or simmering may be detected from fluctuations in angle of a part of the liquid surface. As can clearly be observed in a clear vessel, the liquid surface remains substantially horizontal during heating, exhibits some local variation in angle during simmering, and significant variation in local surface angle during boiling, because of increased turbulence or agitation of the liquid.

One embodiment that uses optical reflection from the liquid surface is shown in Figure 14. An emitter 48 is located in the bottom of the reservoir 5, and arranged to emit electromagnetic radiation towards the surface of the liquid from below. The emitted beam is sufficiently broad to illuminate a wide area of the surface at all liquid levels above a predetermined minimum level, or the beam may be narrow and scanned across the surface, using a beam scanner similar to those used in bar code readers. A detector 49 is located in the bottom of the reservoir 5 at the opposite side, and is arranged to receive electromagnetic radiation reflected from at least part of the liquid surface. The emitter 48 and/or the detector 49 may be sealed within corresponding apertures in the element plate 12, or in an annular adaptor sealed around the periphery of the element plate 12.

The electromagnetic radiation may be narrow band radiation and the detector 49 may be arranged to detect in the narrow band, to reduce the effect of ambient radiation. For improved signal to noise ratio, the output of the emitter 48 may be modulated and the detector circuitry associated with the detector 49 may include a band-pass filter or phase-locked loop. The modulation may be code modulation, and the detector circuitry may include a code demodulator.

The radiation may be optical or near-optical, such as infrared. The emitter 48 may be an infrared LED.

Total internal reflection from the surface of the liquid occurs above the critical angle for the interface between the air and the liquid, as defined by:

$$\Theta_C = \sin^{-1}(n_2 / n_1)$$

where for water with infrared, the refractive index n_1=1.33 and for air, the refractive index n_2=1.00, hence the critical angle to the normal to the surface is about 50°.

The angle from the emitter 48 to the surface to the detector 49 may or may not be above the critical angle, depending on the liquid level. However, turbulence caused by boiling or simmering will cause the normal of the surface to fluctuate locally from the vertical, so that the intensity of radiation reflected from the surface and received by the detector 49 as a result of total internal reflection will also fluctuate. The control 10 detects these fluctuations from the detector 49 and determines a boiling or simmering condition therefrom. In particular, simmering may be detected by small fluctuations in the surface angle. However, boiling causes much larger, chaotic fluctuations in the surface which produce a different pattern at the detector 49.

The radiation from the emitter 48 may also be reflected from the underside of the lid 8 onto the detector 49. The intensity of this reflection will be substantially constant and therefore provides an offset in the intensity detected by the detector 49. This offset may not affect the degree of fluctuation of intensity detected by the detector, but may be used to detect whether the lid 8 is present and/or closed. Hence, the control 10 may be arranged to detect the presence of this offset, and provide an indication that the lid 8 is not present or is not closed in response thereto. Alternatively or additionally, the control 10 may prevent a heating operation if the lid 8 is detected not to be present or closed. Ultrasound may be used as an alternative to electromagnetic radiation for this purpose. Instead of the emitter 48, a light source may used to illuminate the reservoir 5 internally, and the light reflected from the underside of the lid 8 may be detected.

Other parts of the appliance, such as the internal walls of the reservoir 5 or a water window into the reservoir may cause reflection or distort the reflection. For example, specular or diffuse reflections may occur from a stainless steel, glass or plastic wall. These reflections will generally cause a constant offset at the detector 49 and therefore be compensated for by the control 10.

In a variant shown in Figure 15, the emitter 48 and detector 49 are both located at or towards the upper part of the reservoir 5, so as to detect radiation reflected off the surface of the liquid from above the surface.

In another variant shown in Figure 16, the emitter 48 and the detector 49 are placed on opposite sides of the liquid surface, so as to detect the intensity of radiation that is not reflected, which will also fluctuate with turbulence.

In the variants of Figures 14 to 17 the radiation may be partially absorbed by water vapour or steam above the liquid surface or deflected by water movement and/or bubbles within the body of the water . This absorption may be monitored by the control 10 and used to detect the state of the water or alternatively the controller can compensate for the variation caused by the absorption and/or deflection.

In a variant of the embodiments shown in Figures 14 to 17, ultrasonic rather than electromagnetic energy is emitted towards the surface; fluctuations in the amplitude of the reflected and/or transmitted ultrasound are detected by the control 10, which determines a boiling or simmering condition therefrom.

In any of the variants discussed above which use optical or ultrasonic energy to detect surface agitation, the energy is preferably concentrated on an area of the surface that is small enough to detect local fluctuations in the surface angle, without the detected fluctuations cancelling each other out.

In the variants discussed above with reference to Figures 14 and 15, the emitter 48 is separate from the detector 49, and reflection is detected at an acute angle to the surface. Alternatively, the emitter 48 and the detector 49 may be substantially collocated, and the detector 48 arranged to detect energy reflected substantially perpendicularly from the surface. The emitter 48 and detector 49 may be located substantially centrally on the element plate, and may also be configured as a level sensor as in the embodiments of Figures 10 and 11. Alternatively, as shown in Figure 17, they may be located to one side of the element plate 12, for example in an annular adaptor as described above. The emitter 48 and detector 49 may be a unitary component, such as an ultrasonic transducer or a retro-reflective optical sensor.

The emitter 48 and/or detector 49 need not be located within the reservoir 5, but may instead be located in some other part of the vessel body 1, such as the handle 9, and arranged to emit or receive energy respectively through a window into the reservoir 5. Alternatively, the emitter 48 and/or detector 49 may be located in the power base 1 and respectively emit or receive energy via a window in the base of the vessel body 1. The energy need not be incident directly on the surface of the liquid from the emitter 48, but may instead be reflected or refracted onto the surface of the liquid, for example by an optical or acoustic reflector or refractor, or an optical or acoustic guide. Likewise, the energy need not be received directly by the detector 48, but may be reflected or refracted from the surface onto the detector 49. The emitter 48 and detector 49 may be provided within a module that is fitted or retrofitted to the vessel body 1 or base 2, or is separate from the body 1 and from the base 2.

One example of signal processing to detect fluctuations in reflected or transmitted emery will now be described with reference to Figure 18. An IR signal is generated with a square wave of 2.35 kHz. The received IR is amplified and filtered using a band-pass filter with a centre frequency of 2.35 kHz and a –3 dB bandwidth of ± 470Hz. The amplitude of the received signal is determined over 32 cycles of the 2.35 kHz signal (taking approximately 13.6 mS) using quadrature amplitude measurement (samples at intervals of 90° and 180° phase angles), as shown in Figure 18.

Because V_1 and V_3 are 180° out of phase, we can determine the exact offset voltage:

$$V_{offset} = (V_1 + V_3) / 2$$

Using the offset voltage, we can then determine the real peak voltage from two measurements that are exactly 90° out of phase:

$$V_{pk} = SQRT\ [\ (V_1 - V_{offset})^2 + (V_2 - V_{offset})^2\ ]$$

In this way, the offset voltage is compensated and any drift in the signal caused by variation in temperature or components is rejected.

This is repeated 25 times (taking approximately 340mS), during which the minimum and maximum amplitudes are determined. The difference between the minimum and maximum is a measure of the turbulence or agitation of the liquid. This method may be performed by the control 10, or by a dedicated circuit which outputs the measure of agitation or turbulence.

Heating Control

In the above embodiments, the control 10 may vary the heating of the water in response to the detected measure of agitation or turbulence, for example by continuously varying the heating power, or by varying the duty cycle with which the heating element is switched on and off. The control 10 may operate a feedback loop to vary the heating of the water to achieve a substantially constant level of agitation or turbulence; this method is particularly advantageous for applications where the liquid should preferably be kept at a simmer so as to produce some steam for heating purposes, such as in Turkish tea makers, samovars or humidifiers. Alternatively or additionally, the power output of the heater(s) may be controlled according to the level of liquid. The level may be detected by means of a level sensor as described above. In particular, the power output for a keep warm function may be controlled according to the detected level.

The keep warm mode of the vessel may be entered after the heating mode is terminated, for example in response to detection of boiling. Alternatively, the keep warm mode may be switched independently of the heating mode. Heating in keep warm mode may be regulated by controlling the power level of the heater, or by pulsing the heater on and off with a duty cycle that is varied so as to achieve the desired average level of heating. Periodically, such as after a predetermined number of cycles, the heating mode may be entered again to bring the water back to boiling and the keep warm mode is then entered once more.

The vessel may be provided with a control that detects when the water has reached a low simmer and/or a full boil, for example as described above; the keep warm mode may then be entered, or heating may be terminated altogether. In keep warm mode, a timer may be set such that heating mode is entered periodically, such as every 2 minutes, so as to bring the water up to the boil or simmering point. The control monitors the agitation of the water, which is indicative of simmering. Preferably, once the keep warm mode is entered, the control continues to monitor the agitation of the water, and reduce or eliminate the keep warm heating when a simmer is detected.

In this way, a steam sensor is no longer essential; this may be advantageous, because condensation in the control may be avoided, and the cost of a steam sensor need not be incurred. A thermostat may also be provided to detect when the water has cooled below a minimum threshold, such that the keep warm mode needs to be entered. However, it is preferable that the heat input during keep warm mode is varied to match the heat loss from the water, such that cycling of the thermostat is avoided.

Level Detection on or before Heating

At least some of the level sensor or sensing techniques described herein may be used to detect the level or volume of liquid in a liquid heating vessel on or before commencement of a heating operation, to determine whether the liquid level is above a predetermined maximum and/or below a predetermined minimum level; if not, the heating operation may be inhibited, or an indication given to the user. In this way, unsafe operation of the vessel may be prevented. The predetermined maximum and/or minimum may be set according to the operational parameters of the vessel, for example to correspond to maximum and minimum levels for safety purposes, or may be altered by the user, for example if a user wants to save energy by never heating more than a particular volume of water.

Additionally or alternatively, at least some of the level sensing or agitation or turbulence detection means disclosed herein may be used to detect whether there is substantially no liquid in the vessel on or before commencement of a heating operation; if so, the heating operation may be inhibited, or an indication given to the user. For example, a detector for detecting reflection from the surface of the liquid may detect no reflection from the surface and this may be taken as an indication that there is no liquid present. Alternatively, a capacitative detector may detect that there is no liquid present.

Level Detection on Filling

At least some of the level sensor or sensing techniques described herein may be used to detect the level or volume of liquid in a liquid heating vessel while the vessel is being filled. A warning indication may be made to the user when a predetermined maximum level has been exceeded. In the case of the cordless vessel described above, the vessel body 1 may include a rechargeable power source so that the control may perform level detection when the vessel body 1 is removed from the base 2. The predetermined level may be set by the user, for example by means of the user interface 11. Preferably, this setting may be changed even when the vessel body 1 is removed from the base 2. For example, the user may select between two or more predetermined levels, such as full (e.g. 1.7 litres), ecological (1 litre), or single cup. If the predetermined level is exceeded, the user interface 11 may give the user the option to change to a higher level and continue filling, or empty out some of the water until the current level is reached.

Self-descaling

The control may perform descaling of the vessel automatically when excess scaling is detected, for example by any one of the techniques described above. When the control next detects that the vessel is empty, it switches on the heating element to force a dry boil condition. This may be done automatically, but for safety reasons it is preferred that the vessel indicates to the user that a forced boil is required, and then forces a dry boil in response to a user actuation. The dry boil condition may be maintained for a predetermined length of time or until the element plate 12 reaches a predetermined temperature. The heating of the element plate 12 during a dry boil condition tends to shed scale.

It is preferred that the vessel is completely empty before a forced dry boil, otherwise the forced boiling of liquid within the vessel will deposit more scale. Level detection may not be sufficiently sensitive to detect the difference between a low level of water and no water at all. Hence, during an initial stage of forced dry boil, the temperature rise of the element plate 12 may be sensed and the forced dry boil terminated if the rate of temperature rise is below a predetermined level, which may indicate that heat is being lost from the element plate 12 due to boiling.

Alternative Embodiments

In addition to the variants mentioned above, other variants are envisaged as falling within the scope of the invention. For example, the present invention is not limited to kettles and controls therefore; aspects of the invention may be applied to wasserkochers, coffee makers such as moka makers, Turkish tea makers, samovars, water boiling urns, pans, sauce makers, steamers, chocolate fountains, fondues, steamers, slow cookers and milk frothers, for example.

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. A method of detecting boiling or simmering in a liquid heating vessel, comprising detecting agitation or turbulence in the surface of the liquid and detecting boiling or simmering in response to said detected agitation or turbulence.

2. The method of claim 1, wherein the step of detecting agitation or turbulence in the surface of the liquid comprises detecting fluctuations in the level of at least a part of the liquid surface.

3. The method of claim 1, wherein the step of detecting agitation or turbulence in the surface of the liquid comprises detecting fluctuations in the angle of at least a part of the liquid surface.

4. The method of claim 3, wherein the step of detecting fluctuations in the angle comprises emitting energy towards said part of the surface and detecting fluctuations in reflection of the energy from the surface.

5. The method of claim 3, wherein the step of detecting fluctuations in the angle comprises emitting electromagnetic radiation towards said part of the surface and detecting fluctuations in transmission of the energy through the surface.

6. The method of claim 4 or 5, wherein said energy comprises electromagnetic radiation.

7. The method of claim 4 or 5, wherein said energy comprises ultrasound.

8. The method of any one of claims 4 to 7, wherein said step of detecting fluctuations comprises determining variation in the amplitude of received energy using quadrature amplitude measurement.

9. The method of any one of claims 4 to 8, including compensating for reflections and/or distortions of the energy by a part of the liquid heating vessel.

10. The method of any one of claims 4 to 9, including detecting reflection of said energy from the underside of the lid.

11. The method of claim 10, including indicating whether the lid is determined to be closed.

12. The method of claim 10 or 11, including inhibiting a heating operation if the lid is not determined to be closed.

13. The method of claim 1 or 2, wherein said step of detecting agitation or turbulence comprises detecting fluctuations in capacitance of the liquid.

14. The method of any preceding claim, including means for varying heating of the liquid in response to the detected agitation or turbulence so as to maintain a substantially constant level of simmering or boiling.

15. A method of detecting the state of a lid of a liquid heating vessel, comprising detecting reflection from the underside of the lid and determining from said reflection whether the lid is closed.

16. The method of claim 15, including emitting energy towards the underside of the lid and detecting reflection of said energy from the underside of the lid.

17. The method of claim 16, wherein said energy comprises electromagnetic radiation.

18. The method of claim 16, wherein said energy comprises ultrasound.

19. The method of any one of claims 15 to 18, including indicating whether the lid is determined to be closed.

20. The method any one of claims 15 to 19, including inhibiting a heating operation if the lid is not determined to be closed.

21. Apparatus for detecting the state of a lid of a liquid heating vessel, comprising a detector for detecting reflection from the underside of the lid and for determining from said reflection whether the lid is closed.

22. The apparatus of claim 21, including an emitter for emitting energy towards the underside of the lid so as to be reflected from the underside of the lid.

23. The apparatus of claim 22, wherein said energy comprises electromagnetic radiation.

24. The apparatus of claim 22, wherein said energy comprises ultrasound.

25. The apparatus of any one of claims 21 to 24, including an indicator for indicating whether the lid is determined to be closed.

26. The apparatus of any one of claims 21 to 25, arranged to inhibit a heating operation if the lid is not determined to be closed.

27. Apparatus for detecting boiling or simmering in a liquid heating vessel, comprising means for detecting agitation or turbulence in the surface of the liquid and means for determining boiling or simmering in response to said detected agitation or turbulence meeting a predetermined criterion.

28. Apparatus according to claim 27, wherein the means for detecting agitation or turbulence in the surface of the liquid comprises means for detecting fluctuations in the level of at least a part of the liquid surface.

29. Apparatus according to claim 27, wherein the means for detecting agitation or turbulence in the surface of the liquid comprises means for detecting fluctuations in the angle of at least a part of the liquid surface.

30. Apparatus according to claim 29, wherein the means for detecting fluctuations in the angle comprises an emitter arranged to emit energy towards said part of the surface and a detector arranged to detect fluctuations in reflection of the electromagnetic radiation from the surface.

31. Apparatus according to claim 30, wherein the emitter and the detector are spaced apart so as to detect reflections at an acute angle to the surface.

32. Apparatus according to claim 30, wherein the emitter and the detector are substantially collocated so as to detect reflections substantially perpendicular to the surface.

33. Apparatus according to claim 30, wherein the means for detecting fluctuations in the angle comprises an emitter arranged to emit energy towards said part of the surface and a detector for detecting fluctuations in transmission of the electromagnetic radiation through the surface.

34. Apparatus according to any one of claims 30 to 33, wherein said energy comprises electromagnetic radiation.

35. Apparatus according to any one of claims 30 to 33, wherein said energy comprises ultrasound.

36. Apparatus according to any one of claims 30 to 35, wherein the detector is arranged to compensate for reflections and/or distortions of the energy by a part of the liquid heating vessel.

37. Apparatus according to any one of claims 30 to 36, wherein the detector is arranged to detect reflection of said energy from the underside of the lid.

38. The apparatus of claim 37, arranged to indicate whether the lid is determined to be closed.

39. The apparatus of claim 37 or 38, arranged to inhibit a heating operation if the lid is not determined to be closed.

40. Apparatus according to claim 27, wherein said means for detecting agitation or turbulence comprises means for detecting fluctuations in capacitance of the liquid.

41. A liquid heating vessel having a level sensor comprising a pressure sensor arranged at or near the bottom of a reservoir of the vessel.

42. A liquid heating vessel having a force sensor arranged to sense a force applied by the vessel to a support surface.

43. The vessel of claim 42, comprising a vessel body and a power base for providing heating power to the vessel, the force sensor being arranged to sense the force applied between the vessel body and the base.

44. The vessel of claim 43, wherein the force sensor is arranged in the vessel body.

45. The vessel of claim 43, wherein the force sensor is arranged in the base.

46. The vessel of any one of claims 43 to 45, wherein the power base is arranged to provide a cordless electrical connection to an electric heater within the vessel body.

47. The vessel of any one of claims 43 to 45, wherein the power base comprises an inductive heater for inductively heating at least a portion of the vessel body.

48. The vessel of any one of claim 47, wherein said portion comprises a floor of the vessel.

49. The vessel of claim 47 or 48, wherein said portion has a Curie temperature above the operational temperature thereof during heating of liquid, but below a temperature sufficient to damage the vessel if heated without liquid.

50. The vessel of any one of claims 42 to 49, including means for calculating the level of liquid in the vessel from said sensed force.

51. The vessel of any one of claims 42 to 50, including means for detecting a change in said sensed force characteristic of a user touching the vessel, and for initiating an action in response thereto.

52. The vessel of any one of claims 42 to 51, including means for detecting a fluctuation in said sensed force characteristic of boiling or simmering of the liquid and for initiating an action in response thereto.

53. A liquid heating vessel having a level or volume sensor comprising means for measuring the resistance of liquid within the vessel and for deriving the level or volume therefrom.

54. A liquid heating vessel having a level or volume sensor comprising means for measuring the capacitance of liquid within the vessel and for deriving the level or volume therefrom.

55. A level sensor for a liquid heating vessel, comprising means for emitting a signal towards the surface of the liquid, and for detecting the signal reflected from the surface of the liquid and thereby determining the level of the surface.

56. The level sensor of claim 55, arranged to determine the level of the surface by measuring the time taken between emission and reception of the signal after reflection from the surface.

57. The level sensor of claim 55 or 56, wherein the signal is pulsed.

58. The level sensor of any one of claims 55 to 57, wherein the signal is modulated.

59. The level sensor of any one of claims 55 to 58, wherein the means for emitting and for detecting the signal are substantially aligned with a central vertical axis of the vessel.

60. The level sensor of claim 59, wherein the level of the surface is determined by detecting the amplitude of the signal reflected from the surface.

61. The level sensor of claim 60, wherein the signal is emitted at an oblique angle to the surface.

62. The level sensor of any one of claims 55 to 61, wherein the signal is an ultrasonic signal.

63. The level sensor of any one of claims 55 to 61, wherein the signal is an electromagnetic signal.

64. The level sensor of claim 63, wherein the electromagnetic signal is a laser signal.

65. A level or volume sensor for a liquid heating vessel, comprising means for emitting ultrasound into the liquid, and means for determining the level or volume of the liquid from a detected ultrasonic resonant frequency.

66. The sensor of claim 65, arranged to vary the frequency of the emitted ultrasound and thereby to detect the resonant frequency.

67. The sensor of claim 65, arranged to detect the amplitude of the resonant frequency and thereby to determine the level or volume of the liquid.

68. The sensor of any one of claims 55 to 62 or 67, wherein said means comprises an ultrasonic transducer.

69. The sensor of claim 68, wherein the transducer comprises an element plate in the base of the vessel.

70. The sensor of claim 69, including means for applying an electric signal to an element of the element plate to generate the ultrasound.

71. The sensor of claim 68, wherein the transducer is coupled to the element plate.

72. A liquid heating vessel including a level sensor according to any one of claims 55 to 71.

73. A method of detecting boiling in a liquid heating vessel, comprising detecting the electrical resistance of liquid in the vessel, and detecting boiling in response to an increase in the detected resistance.

74. The method of claim 73, wherein the resistance is detected by applying a voltage between electrodes in contact with the liquid.

75. The method of claim 74, wherein one of the electrodes comprises a heating element of the vessel.

76. A method of detecting boiling or simmering in a liquid heating vessel, comprising detecting sound emitted by the heating of the liquid, and detecting boiling or simmering when said sound meets a corresponding predetermined criterion.

77. A method of detecting scale deposit on an element plate for a liquid heating vessel, comprising inducing ultrasonic vibration of the element plate at a nominal resonant frequency thereof, detecting the amplitude of the vibration, and determining the existence of scale deposit from the amplitude of the vibration.

78. A method of determining an efficiency rating of use of a liquid heating vessel, comprising measuring a quantity of heated liquid remaining after dispensing from a liquid heating vessel and determining the efficiency rating therefrom.

79. The method of claim 78, further comprising measuring a quantity of liquid heated in the vessel before dispensing, the efficiency rating being determined additionally from the measured quantity of liquid before dispensing.

80. The method of claim 79, wherein the efficiency rating is determined from the average ratio of the quantity of liquid remaining in the vessel after dispensing to the quantity of liquid heated in the vessel before dispensing.

81. A method of detecting a liquid level in a liquid heating vessel, comprising detecting the liquid level on or before commencement of a heating operation of the vessel, and inhibiting heating of the liquid if the detected liquid level exceeds a predetermined maximum level.

82. A method of detecting a liquid level in a liquid heating vessel, comprising detecting the liquid level on or before commencement of a heating operation of the vessel, and providing an indication to a user if the detected liquid level reaches or exceeds a predetermined maximum level.

83. The method of claim 81 or 82, wherein the maximum level is adjustable by the user.

84. The method of claim 83, wherein the maximum level is adjustable by the user when the detected liquid level reaches or exceeds the previously predetermined maximum level.

85. A method of detecting a liquid level in a liquid heating vessel, comprising detecting the liquid level on or before commencement of a heating operation of the vessel, and inhibiting heating of the liquid if the detected liquid level is at or below a predetermined minimum level.

86. A method of detecting a liquid level in a liquid heating vessel, comprising detecting the liquid level on or before commencement of a heating operation of the vessel, and providing an indication to a user if the detected liquid level is at or below a predetermined minimum level.

87. The method of claim 85 or 86, wherein the predetermined minimum level corresponds to the vessel being substantially empty of liquid.

88. A method of descaling an electric liquid heating vessel, comprising detecting whether the vessel is empty and switching on a heating element of the vessel to force a dry boil condition.

89. The method of claim 87, wherein the heating element is switched on automatically after scaling is detected, in response to detection of the vessel being substantially empty.

90. The method of claim 87, wherein the heating element is switched on in response to a confirmation by a user, after detection of the vessel being substantially empty.

91. The method of any one of claims 87 to 90, wherein the step of detecting whether the vessel is empty comprises initiating a heating operation, and detecting whether the vessel is empty according to the rate of temperature rise of said heating element.

92. A method of controlling heating power in a liquid heating vessel, the method comprising detecting an ambient sound level and reducing the heating power when the ambient sound level is low, so as to reduce the noise emitted by heating.

93. An electronic control for a liquid heating vessel, arranged to perform the method of any one of claims 1 to 20 and 73 to 92.

94. A control program comprising program code means arranged to perform the method of any one of claims 1 to 20 and 73 to 92.

95. Apparatus for detecting boiling in a liquid heating vessel, comprising means for detecting the electrical resistance of liquid in the vessel, and means detecting boiling in response to an increase in the detected resistance.

96. Apparatus according to claim 95, including electrodes for making electrical contact with the liquid, and means for applying a voltage between the electrodes.

97. Apparatus according to claim 96, wherein one of the electrodes comprises a heating element of the vessel.

98. Apparatus for detecting boiling or simmering in a liquid heating vessel, comprising an acoustic detector for detecting sound emitted by the heating of the liquid, and means for determining boiling or simmering when said sound meets a corresponding predetermined criterion.

99. Apparatus for detecting scale deposit on an element plate of a liquid heating vessel, comprising means for inducing ultrasonic vibration of the element plate at a nominal resonant frequency thereof, means for detecting the amplitude of the vibration, and means for determining the existence of scale deposit from the amplitude of the vibration.

100. A cordless electrically powered liquid heating vessel connectable by means of a cordless connector to a cordless base, the vessel containing an electronic control and a power supply that is operable to supply power to the electronic control when the vessel is separated from the base, wherein the electronic control is arranged selectively to enter a standby mode, in which the power drawn from the power supply is reduced.

101. The vessel of claim 100, wherein the control is arranged to enter the standby mode after the vessel has been separated from the base for more than a predetermined time.

102. The vessel of claim 100 or 101, wherein the control is arranged to leave the standby mode in response to the vessel being replaced on the base.

103. The vessel of any one of claims 100 to 102, wherein the control is arranged to leave the standby mode in response to a user actuation.

104. A cordless electrically powered liquid heating vessel connectable by means of a cordless connector to a cordless base, the vessel containing an electronic control and a power supply that is operable to supply power to the electronic control when the vessel is separated from the base, wherein the power supply comprises a photovoltaic power supply.

105. An element plate for a liquid heating vessel, including means for inducing ultrasonic vibration of the element plate.

106. The element plate of claim 105, wherein the means for inducing ultrasonic vibration is arranged to induce said vibration during heating of the element plate.

107. The element plate of claim 105 or 106, including an ultrasonic transducer coupled to the element plate.

108. The element plate of any one of claims 105 to 107, having a noise reduction coating and/or treatment.

109. The element plate of claim 108, wherein the noise reduction coating is resin based and includes a non-stick or hydrophobic component.

110. The element plate of claim 108 or 109, wherein the treatment comprises a surface roughening treatment.

111. A liquid heating vessel including an element plate according to any one of claims 105 to 107.

Fig. 1

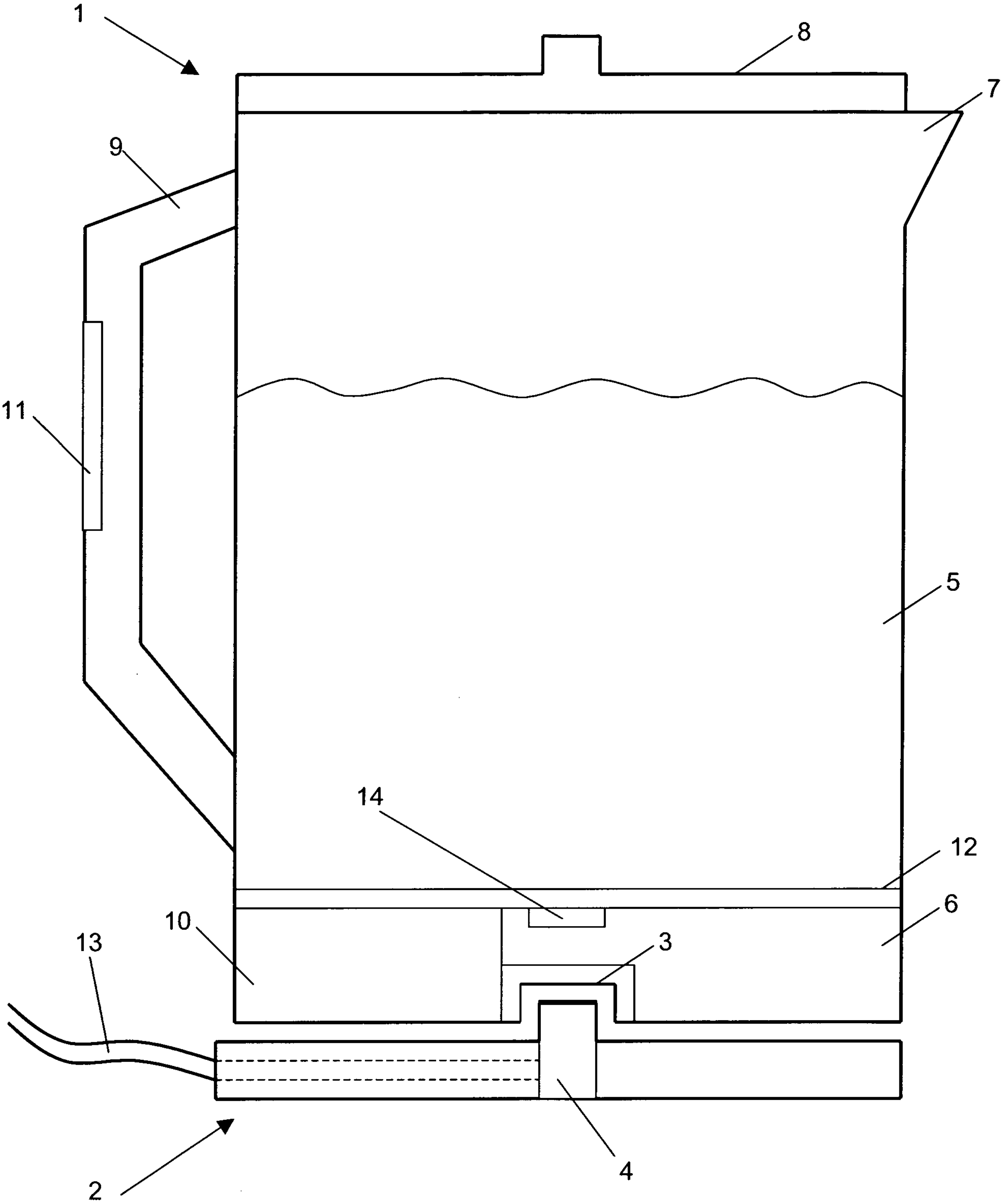


Fig. 2

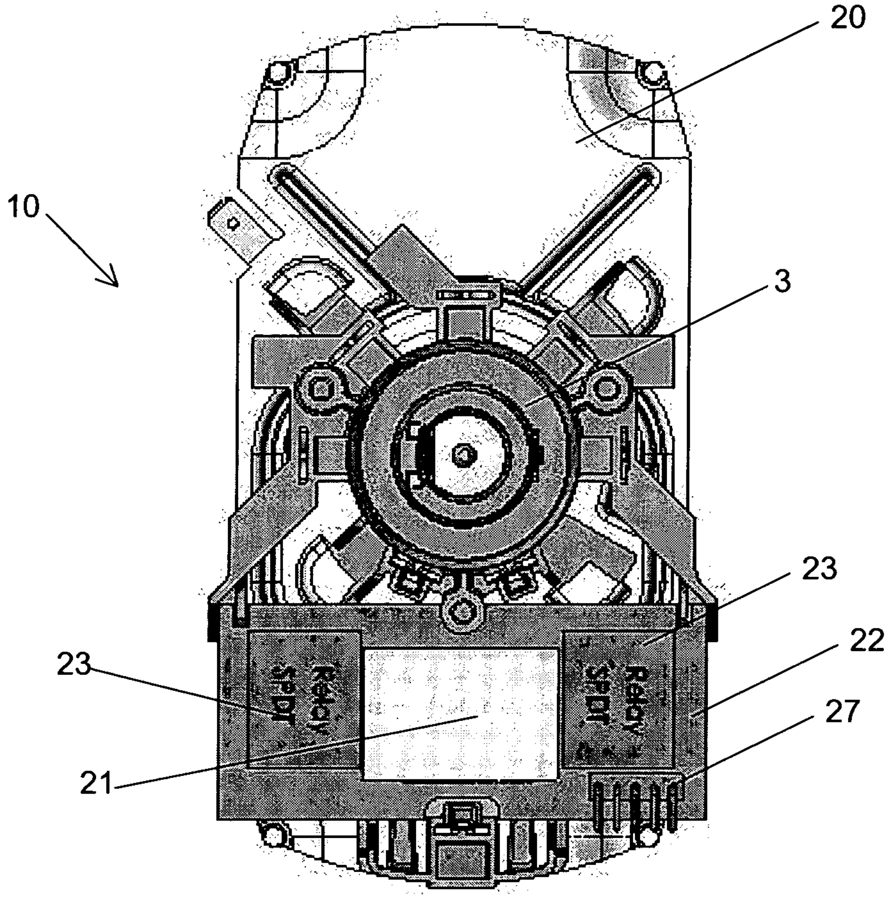


Fig. 3

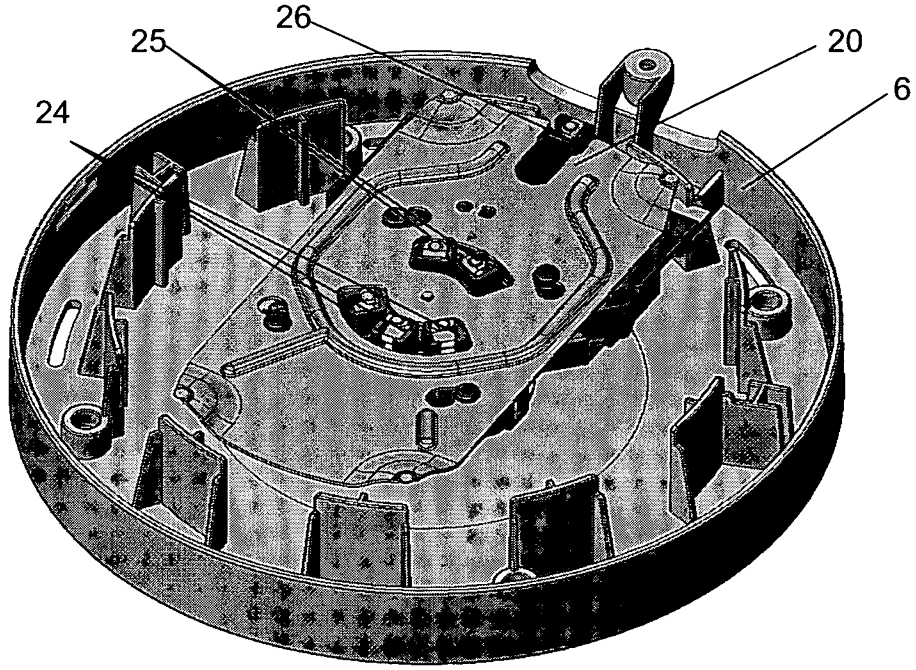


Fig. 4

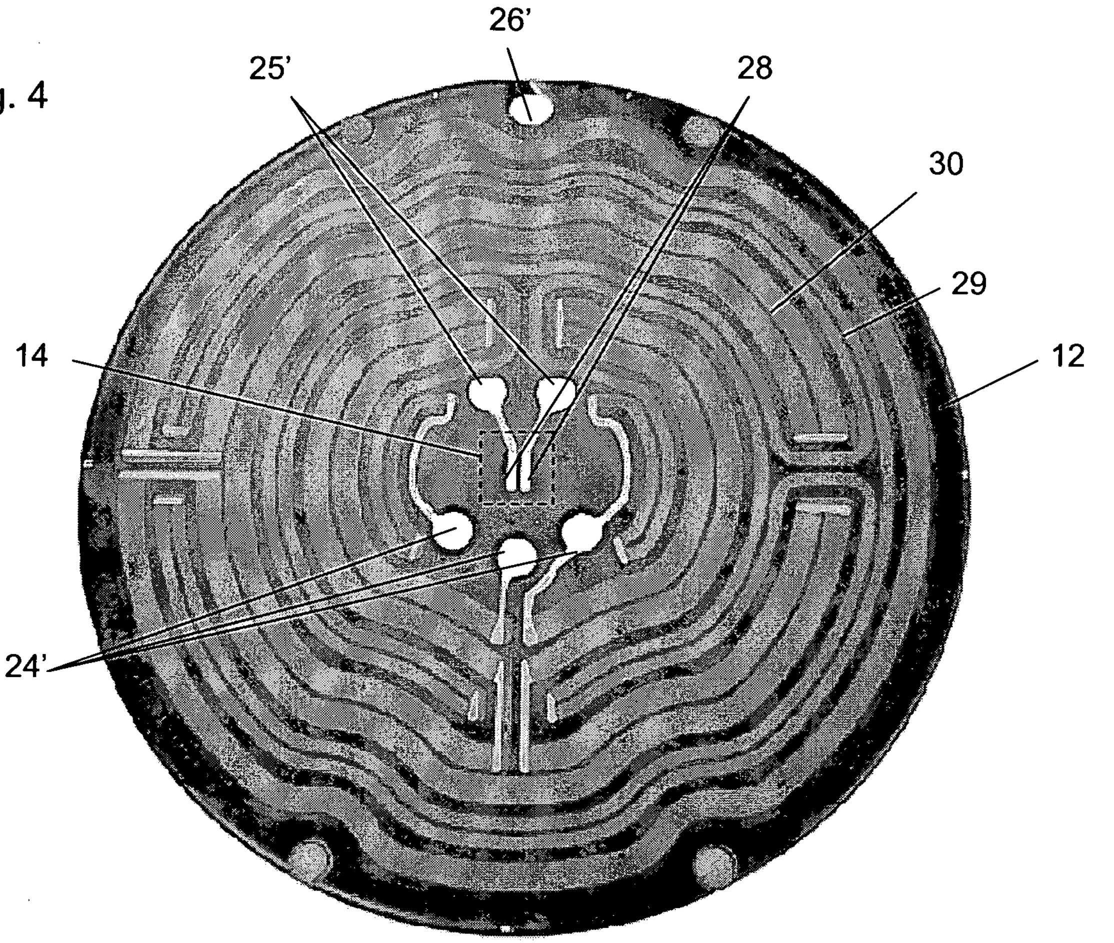


Fig. 5

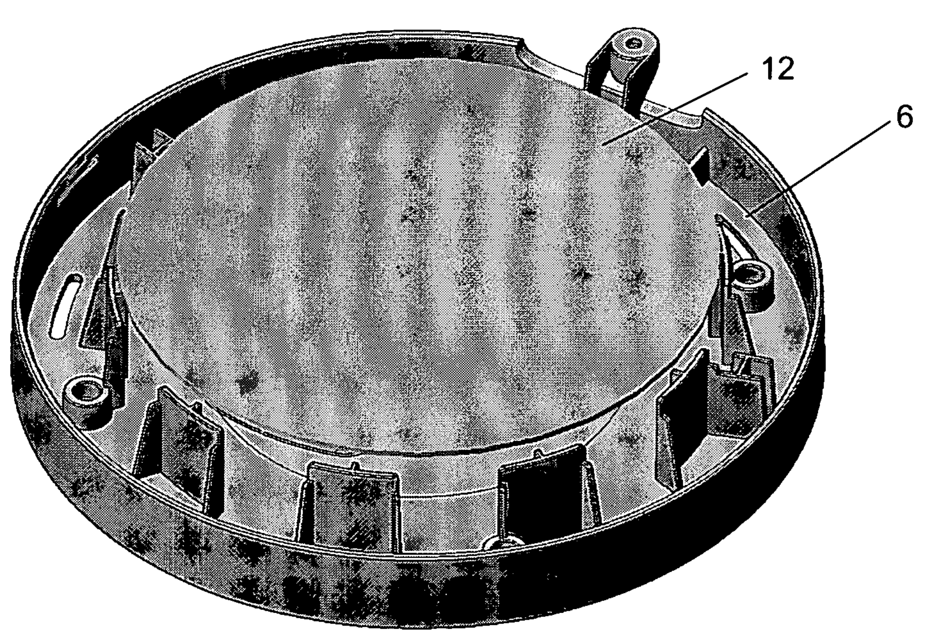


Fig. 6

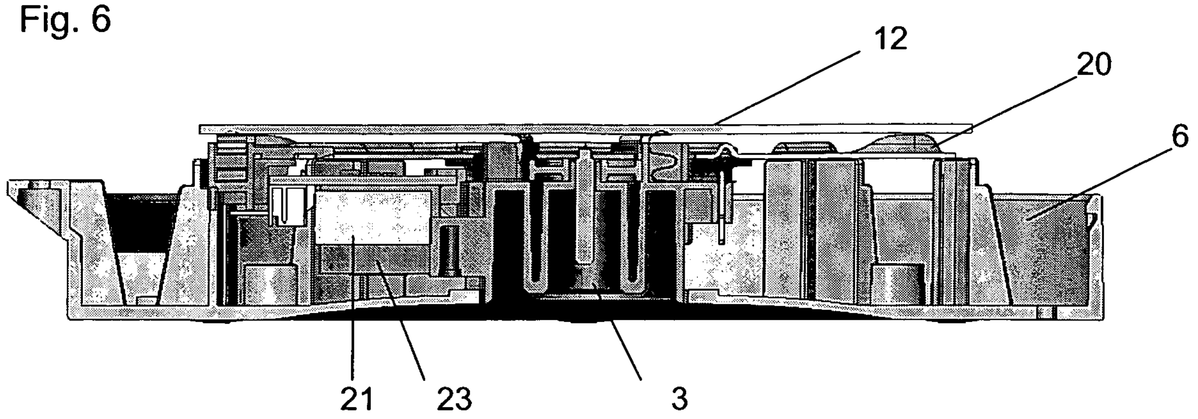


Fig. 7

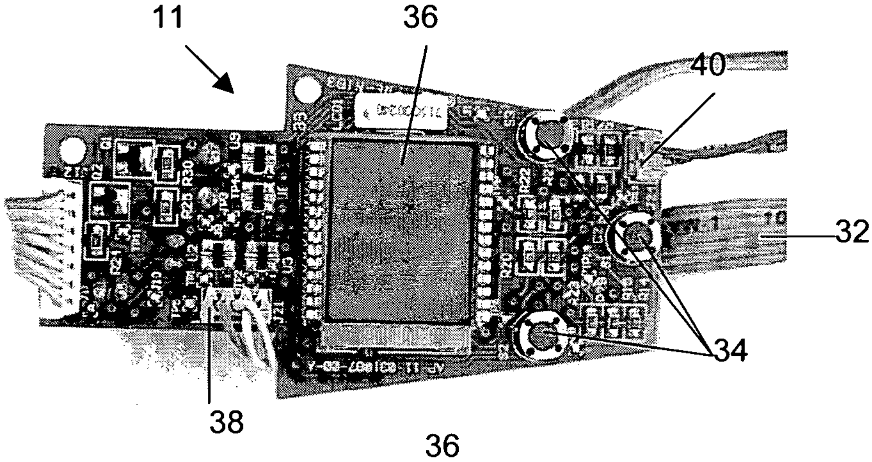
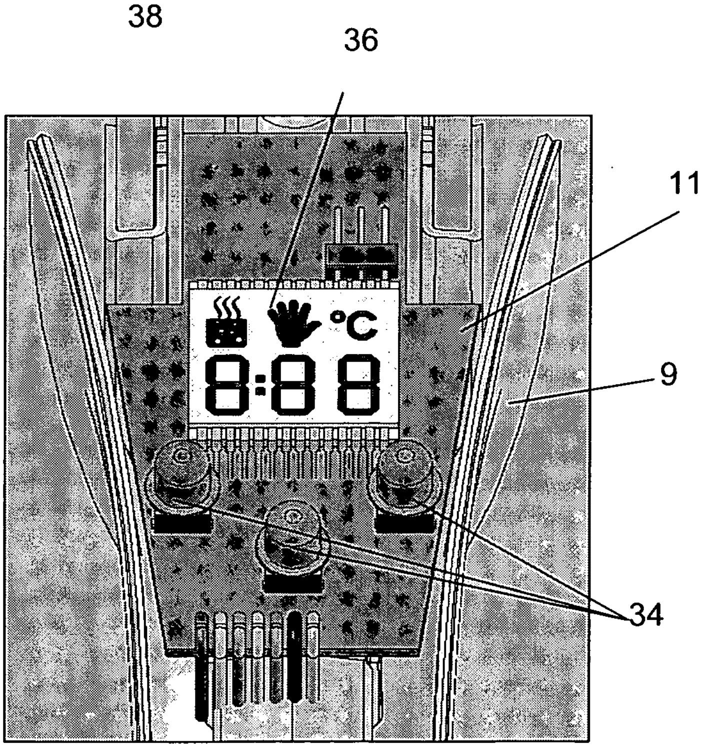
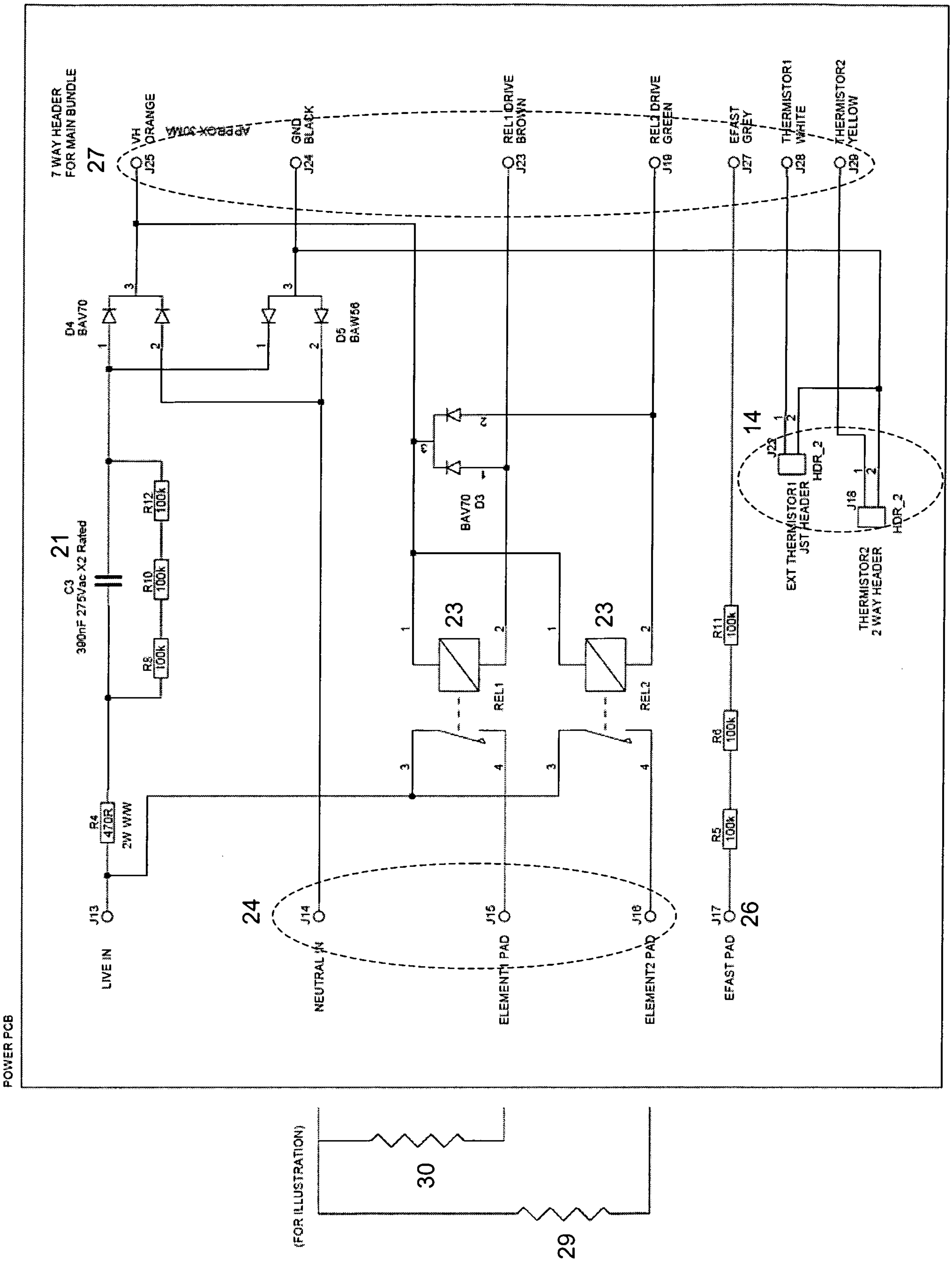


Fig. 8





7 WAY HEADER
FOR MAIN BUNDLE
27
VH
ORANGE
J25
GND
BLACK
J24
REL1 DRIVE
BROWN
J23
REL2 DRIVE
GREEN
J19
EFAST
GREY
J27
THERMISTOR1
WHITE
J28
THERMISTOR2
YELLOW
J29
D4
BAV70
D5
BAW56
BAV70
D3
C3
390nF 275Vac X2 Rated
21
R12
100k
R10
100k
R8
100k
R4
470R
2W WW
23
REL1
REL2
14
J22
HDR_2
J18
HDR_2
EXT THERMISTOR1
JST HEADER
THERMISTOR2
2 WAY HEADER
R11
100k
R6
100k
R5
100k
J13
LIVE IN
24
J14
NEUTRAL IN
J15
ELEMENT1 PAD
J16
ELEMENT2 PAD
J17
26
EFAST PAD
POWER PCB
(FOR ILLUSTRATION)
30
29

Fig. 9a

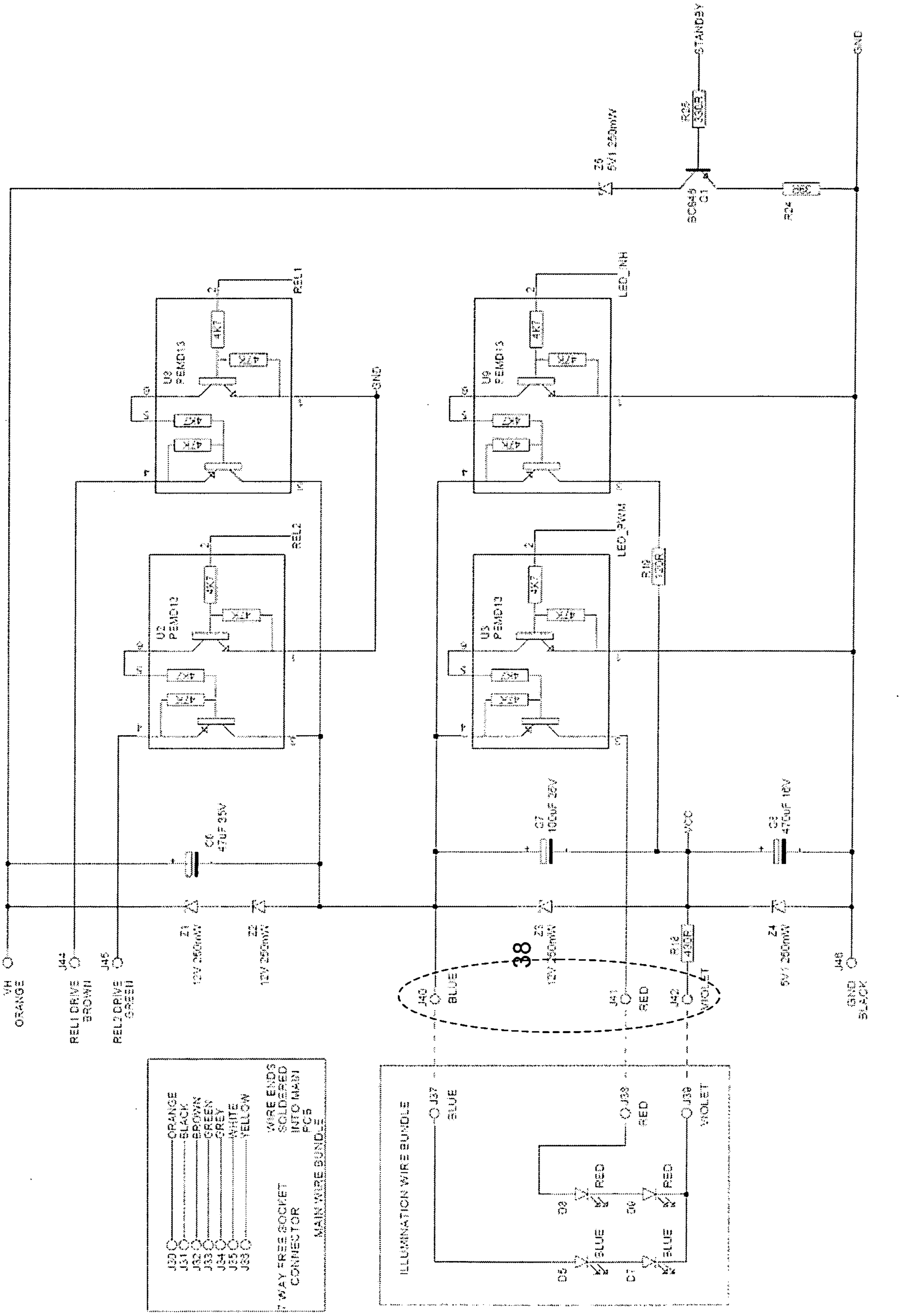

STANDBY
GND
VCC
LED_PWM
PEMD13
38
ILLUMINATION WIRE BUNDLE
MAIN WIRE BUNDLE

Fig. 9b

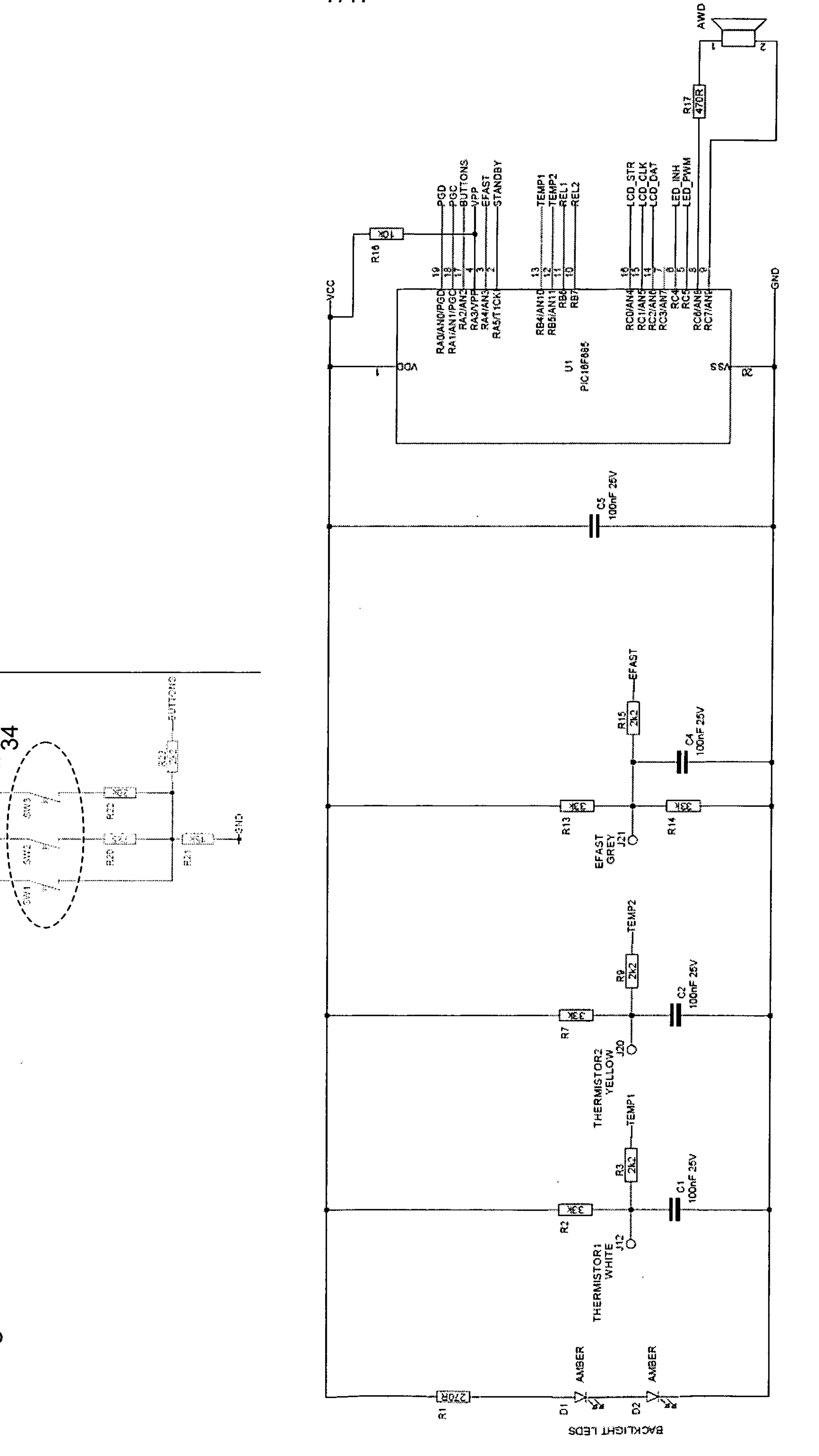

34
USER BUTTONS
BUTTONS
GND
VCC
U1
PIC16F685
C5
100nF 25V
EFAST
GREY
TEMP2
THERMISTOR2
YELLOW
TEMP1
THERMISTOR1
WHITE
AMBER
BACKLIGHT LEDS
AWD
R17
470R
GND

Fig. 9c

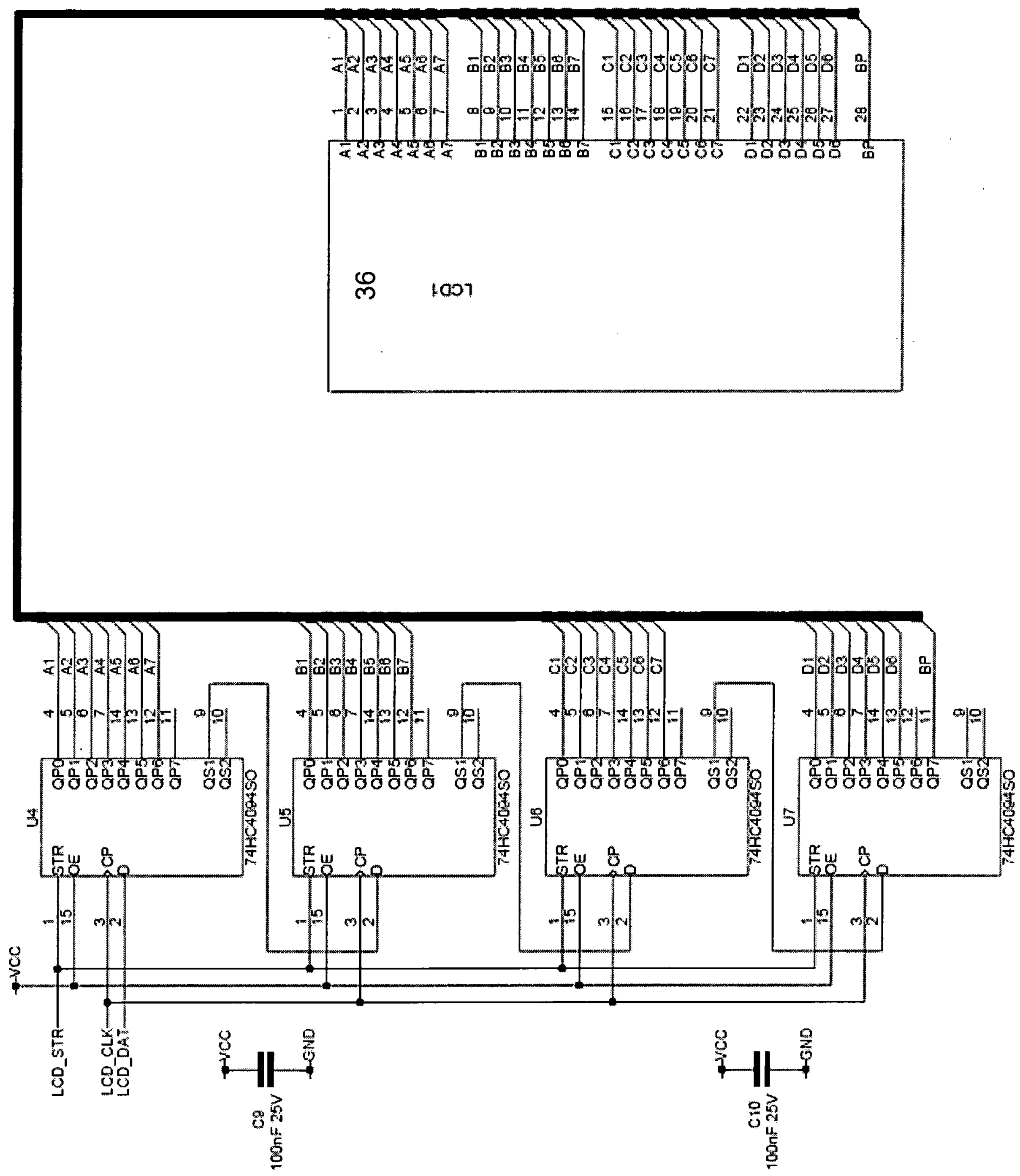

36
LCD1
U4
U5
U6
U7
74HC4094SO
LCD_STR
LCD_CLK
LCD_DAT
VCC
GND
C9
100nF 25V
C10
100nF 25V

Fig. 9d

Fig. 10

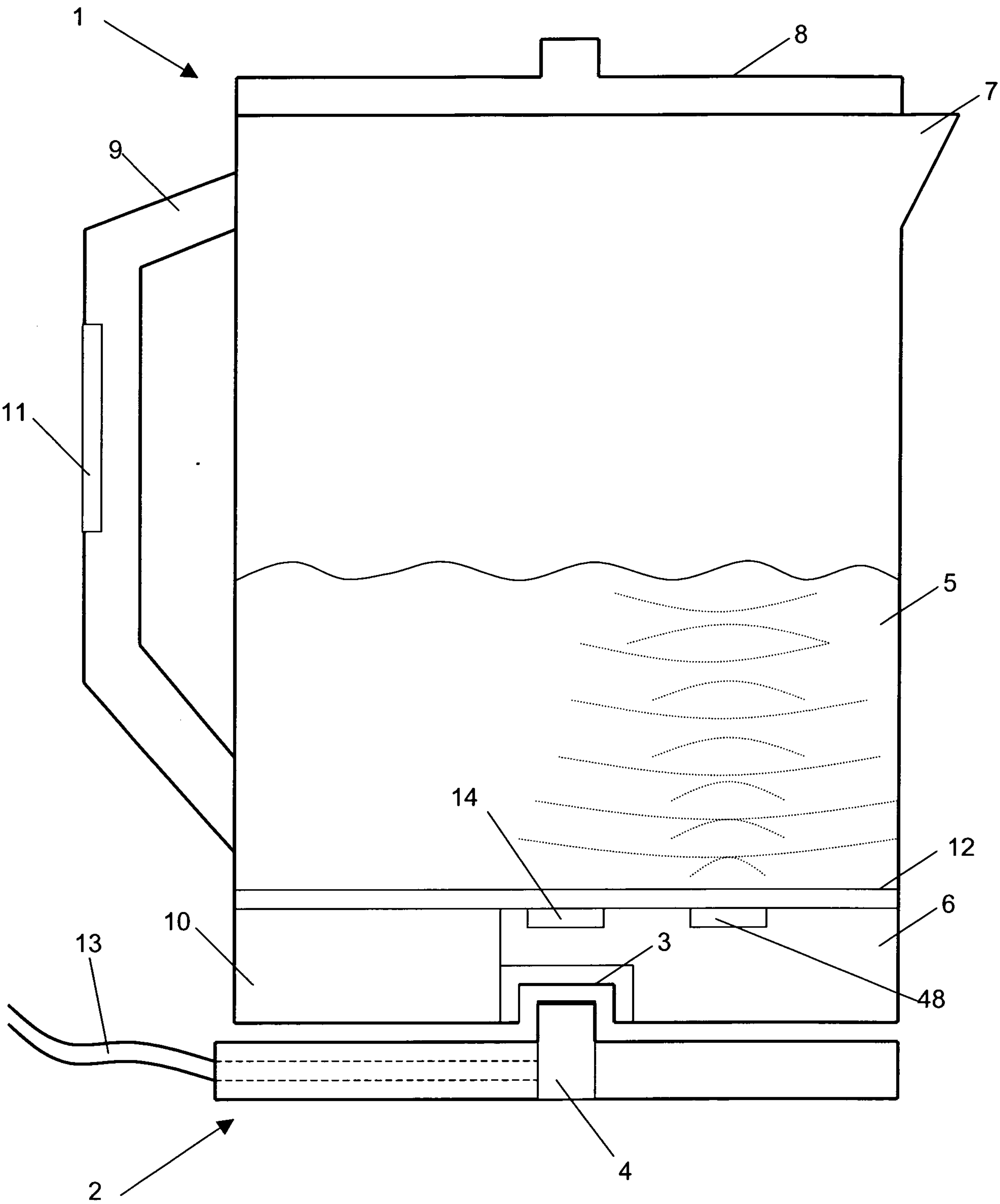


Fig. 11

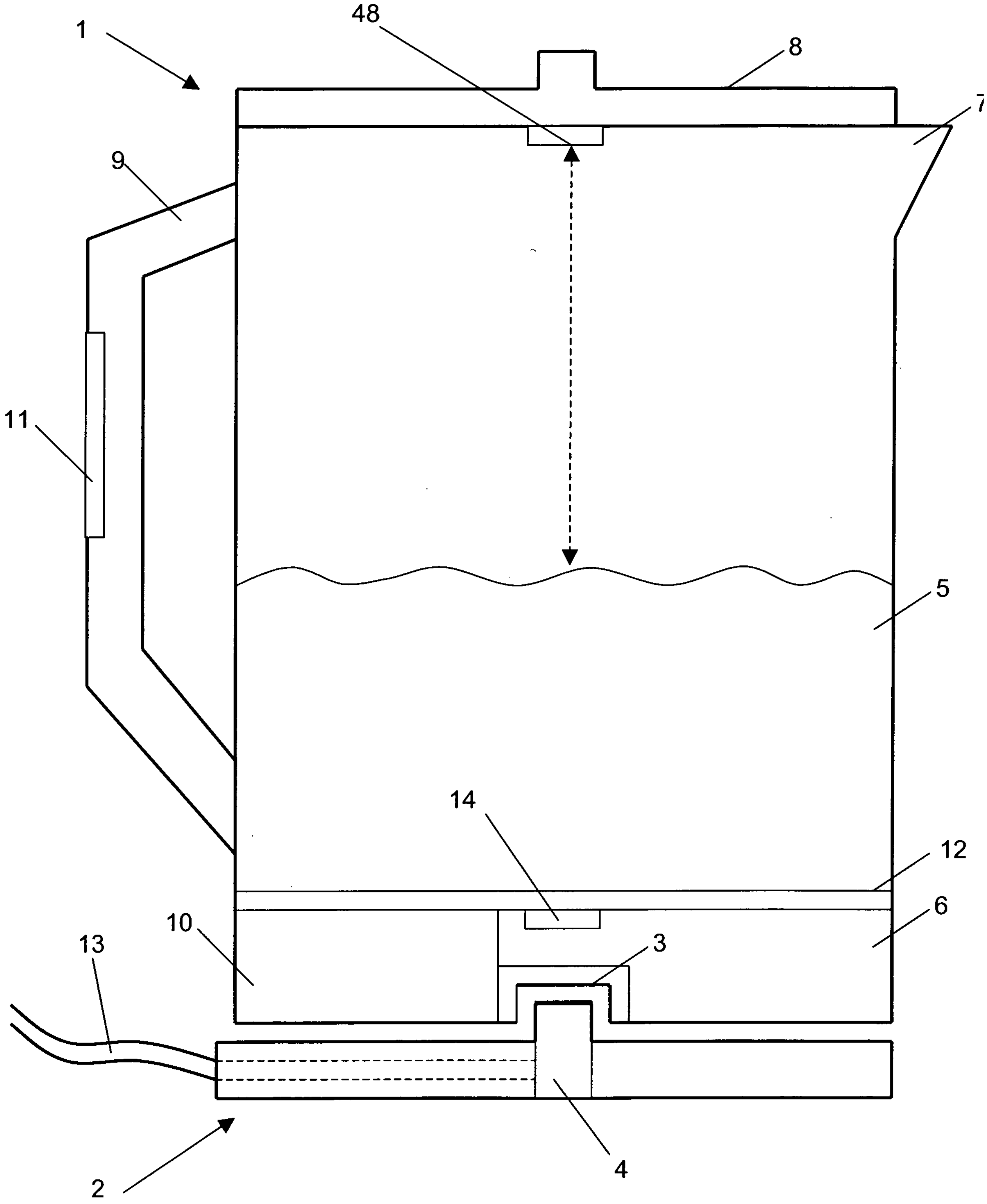


Fig. 12

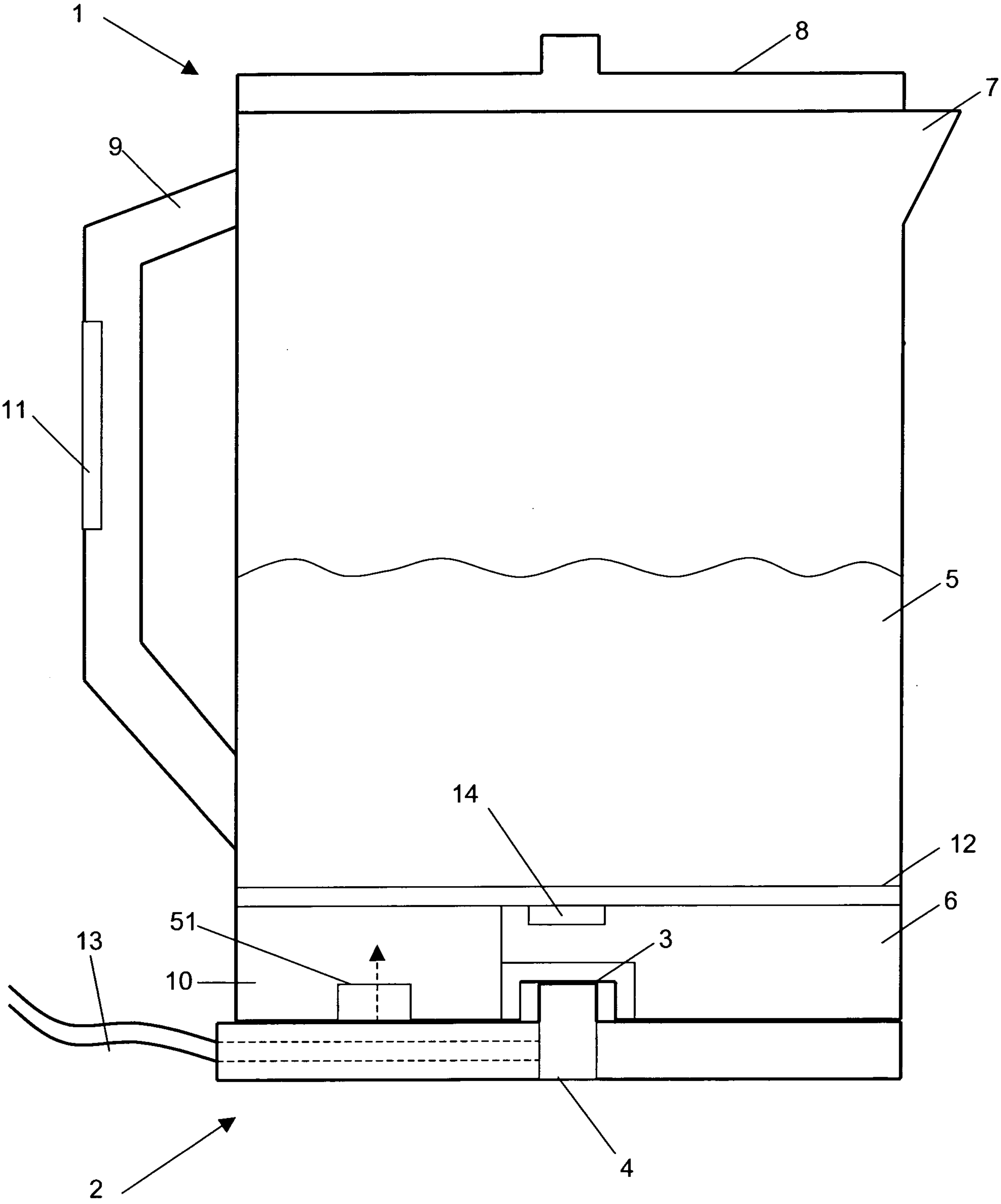


Fig. 13

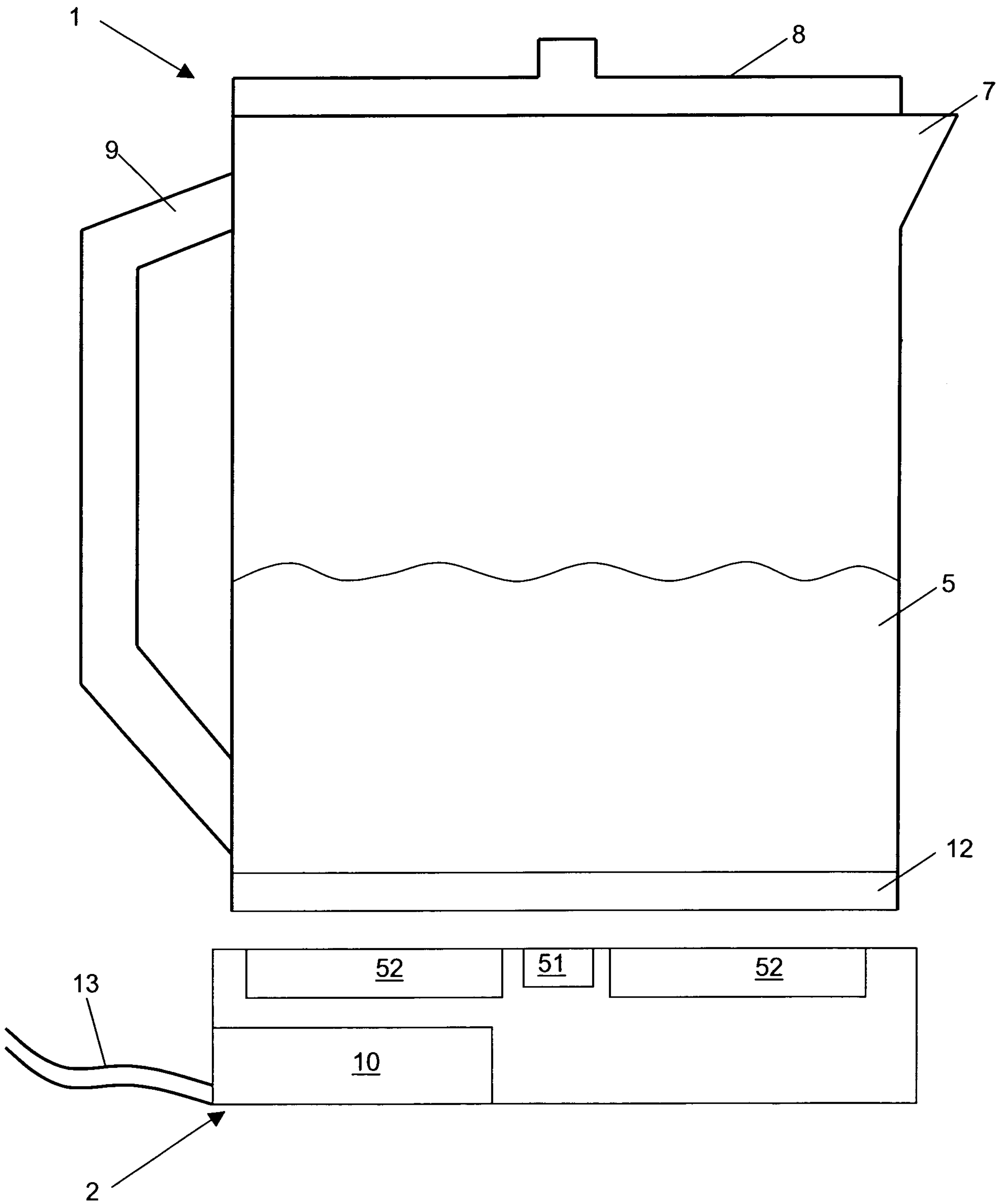


Fig. 14

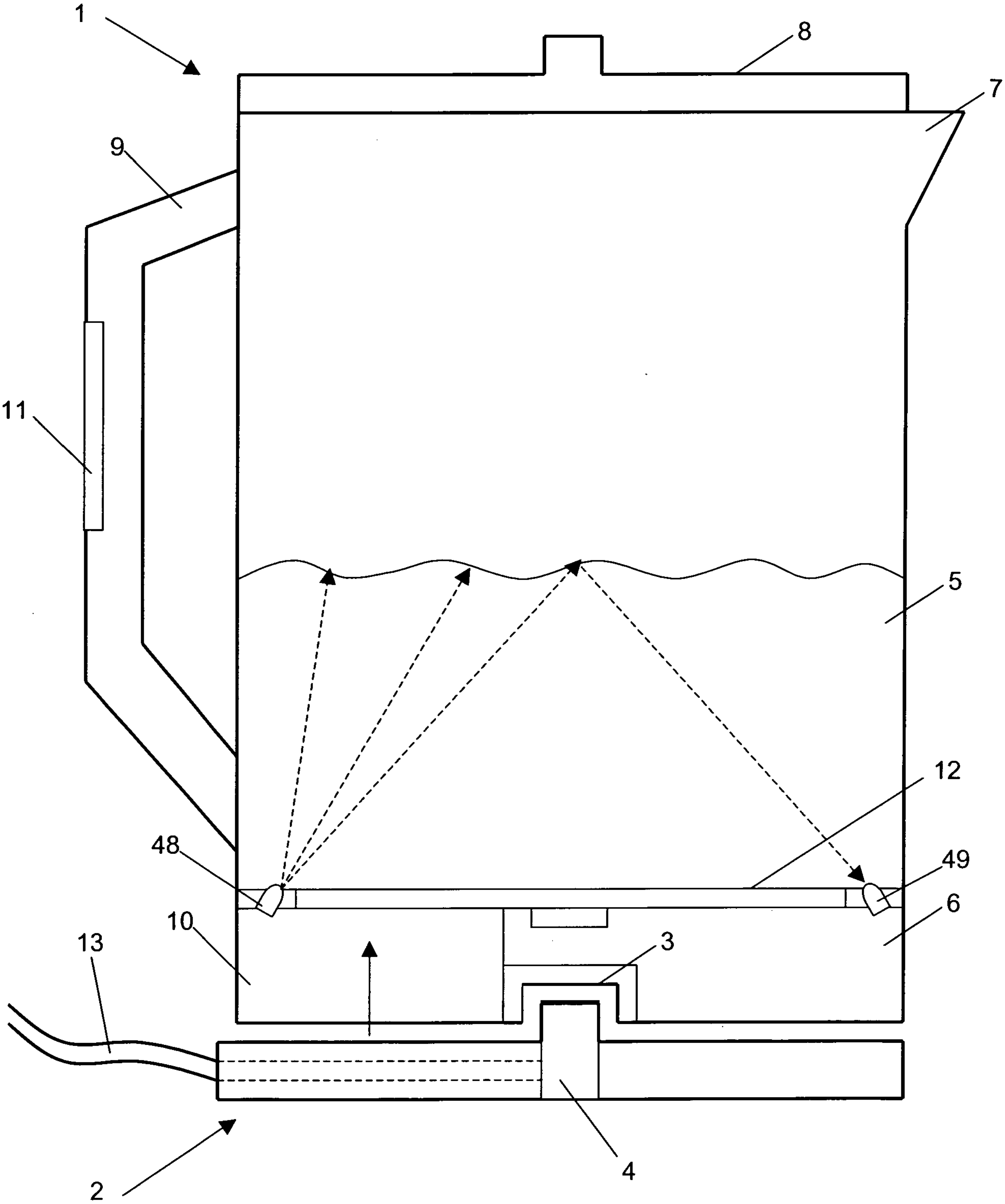


Fig. 15

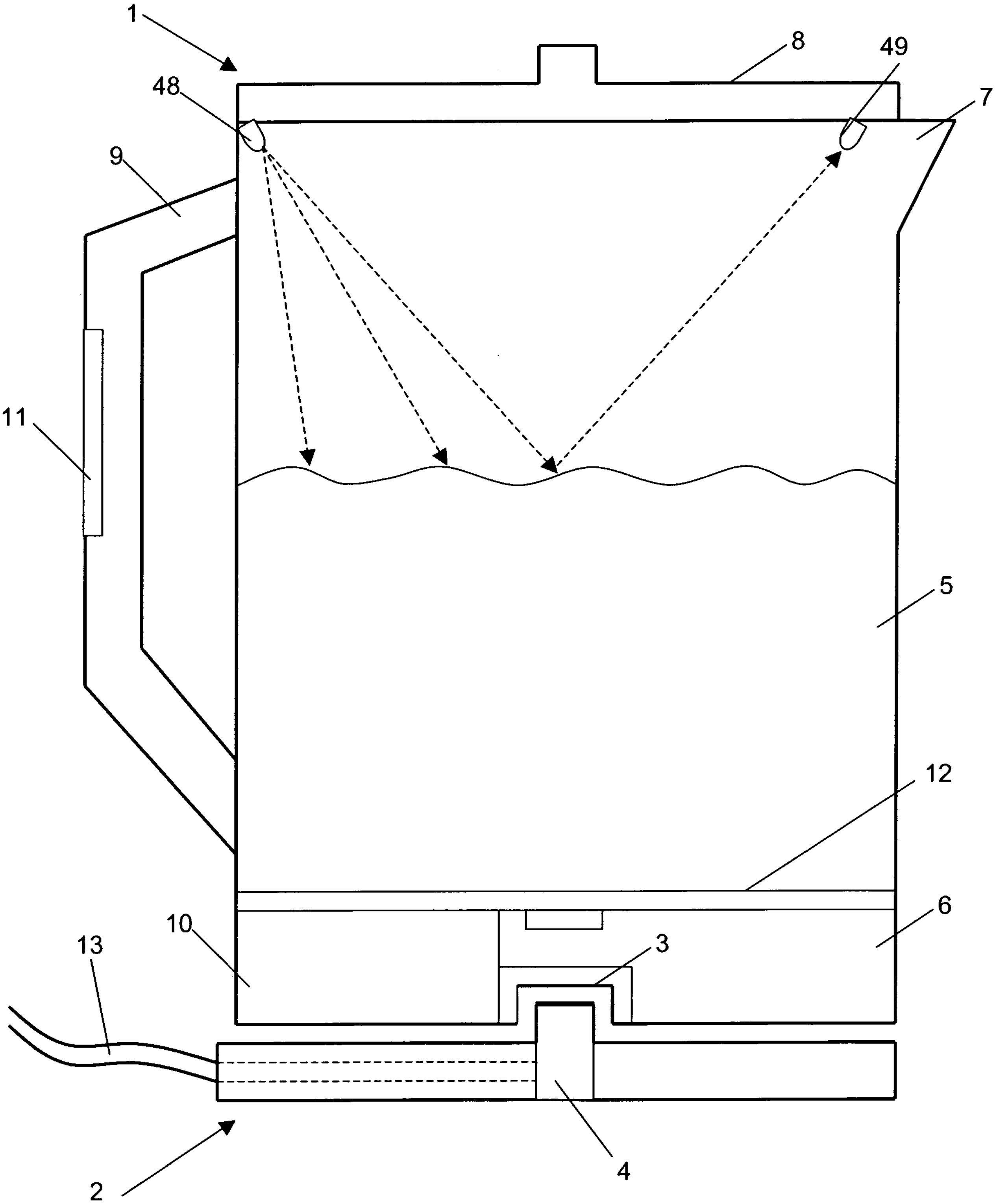


Fig. 16

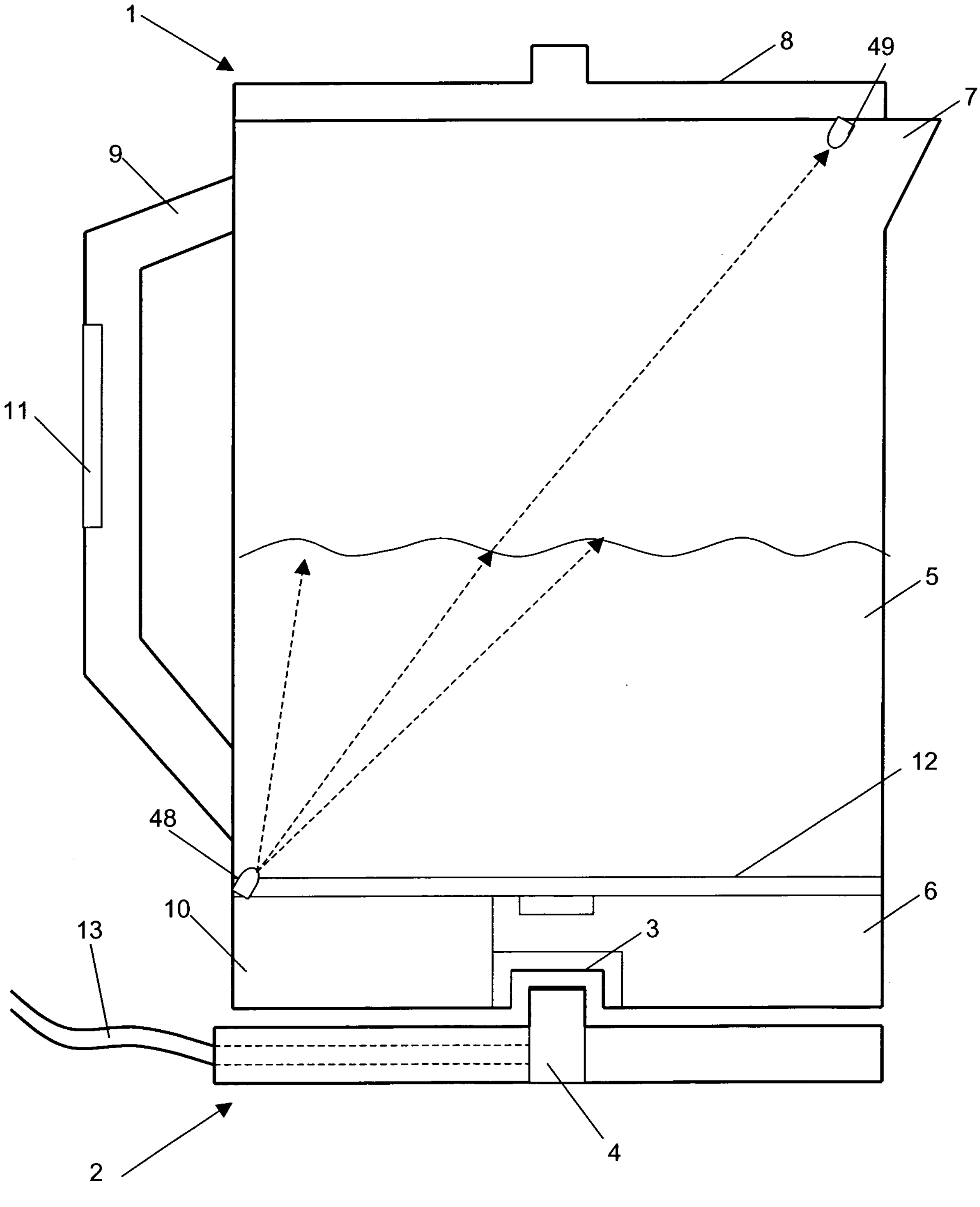


Fig. 17

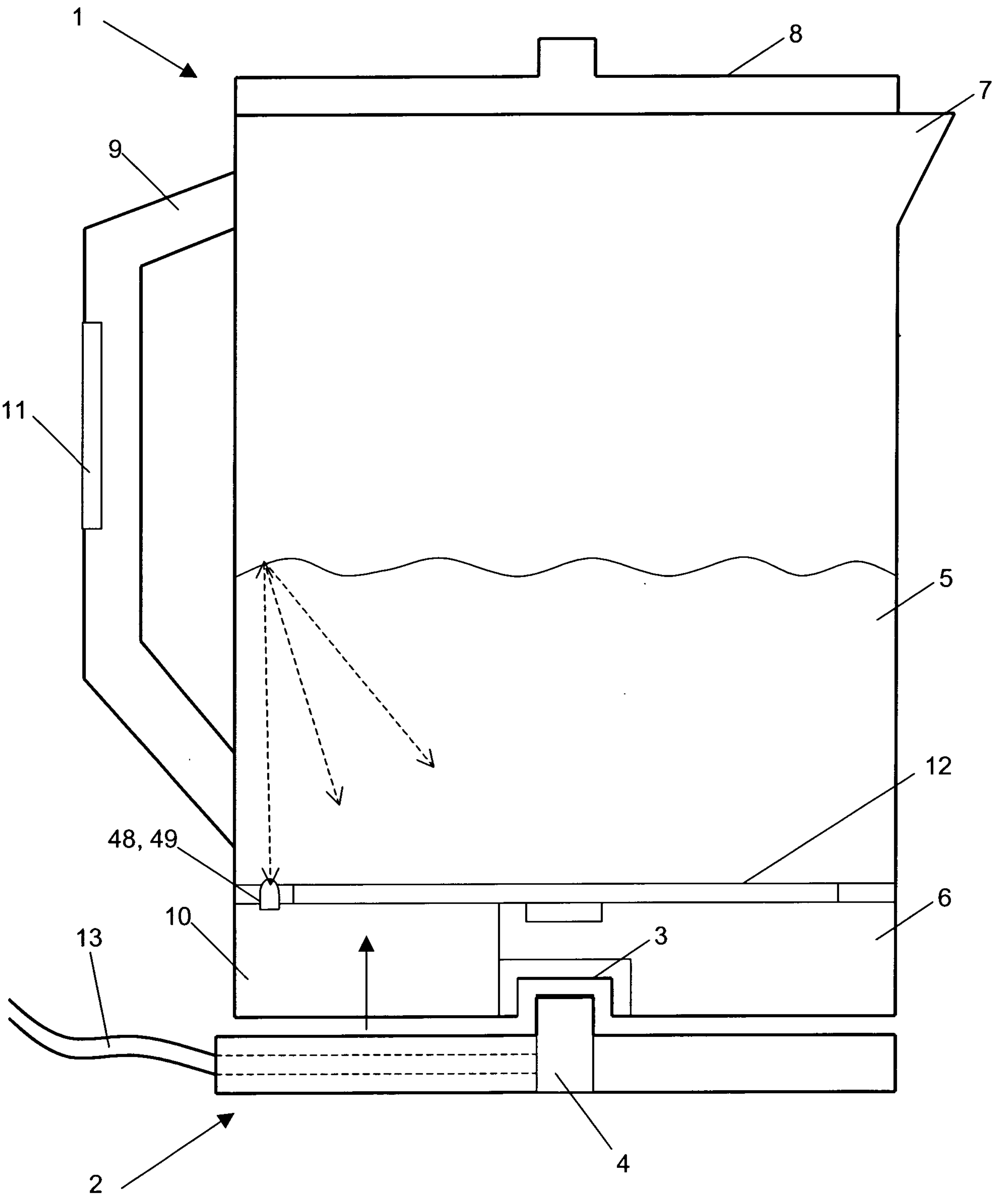
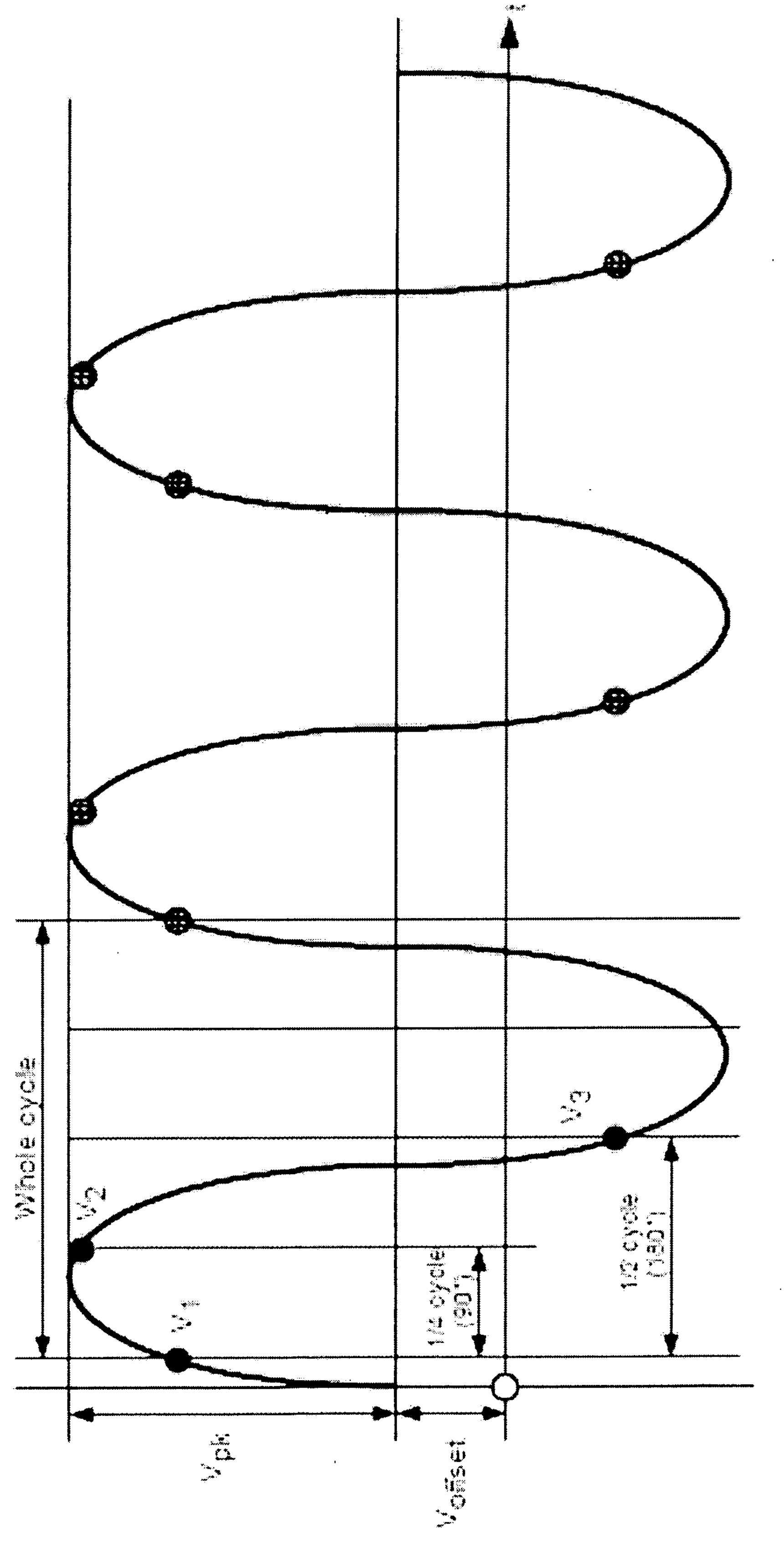


Fig. 18



Applicant's or agent's file reference J50463WO	IMPORTANT DECLARATION	Date of mailing (day/month/year) 19/03/2009
International application No. PCT/GB2008/003737	International filing date (day/month/year) 06/11/2008	(Earliest) Priority date (day/month/year) 07/11/2007
International Patent Classification (IPC) or both national classification and IPC G05D23/00, A47J27/21		
Applicant OTTER CONTROLS LIMITED		

This International Searching Authority hereby declares, according to Article 17(2)(a), that **no international search report will be established** on the international application for the reasons indicated below

1. ☐ The subject matter of the international application relates to:
   - a. ☐ scientific theories
   - b. ☐ mathematical theories
   - c. ☐ plant varieties
   - d. ☐ animal varieties
   - e. ☐ essentially biological processes for the production of plants and animals, other than microbiological processes and the products of such processes
   - f. ☐ schemes, rules or methods of doing business
   - g. ☐ schemes, rules or methods of performing purely mental acts
   - h. ☐ schemes, rules or methods of playing games
   - i. ☐ methods for treatment of the human body by surgery or therapy
   - j. ☐ methods for treatment of the animal body by surgery or therapy
   - k. ☐ diagnostic methods practised on the human or animal body
   - l. ☐ mere presentations of information
   - m. ☐ computer programs for which this International Searching Authority is not equipped to search prior art
2. ☒ The failure of the following parts of the international application to comply with prescribed requirements prevents a meaningful search from being carried out:
   ☐ the description ☒ the claims ☐ the drawings
3. ☐ A meaningful search could not be carried out without the sequence listing; the applicant did not, within the prescribed time limit:
   - ☐ furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
   - ☐ furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
   - ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13*ter*.1(a) or (b).
4. ☐ A meaningful search could not be carried out without the tables related to the sequence listings; the applicant did not, within the prescribed time limit, furnish such tables in electronic form complying with the technical requirements provided for in Annex C-*bis* of the Administrative Instructions, and such tables were not available to the International Searching Authority in a form and manner acceptable to it.
5. Further comments:

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bruno Gamboa Susín

Form PCT/ISA/203 (April 2005)

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 203

The present application contains 111 claims, of which 26 are independent. There is no clear distinction between the independent claims because of overlapping scope. There are so many claims, and they are drafted in such a way that the claims as a whole are not in compliance with the provisions of clarity and conciseness of Article 6 PCT, as it is particularly burdensome for a skilled person to establish the subject-matter for which protection is sought.

The non-compliance with the substantive provisions is to such an extent that a meaningful search of the whole claimed subject-matter could not be carried out (Article 17(2) PCT and PCT Guidelines 9.30).

There being no reasonable basis in the application that clearly indicates the subject-matter which might be expected to form the subject of the claims later in the procedure, no search at all was deemed possible.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2)PCT declaration be overcome.