ABSTRACT

Liquid-heating device (11) for an electric household appliance, the device comprising a main body (1) and a complementary element (3) disposed opposite a face of the main body (1), a liquid circulation channel (4) existing between the complementary element (3) and main body (1), said channel having two ends forming an inlet (5) designed to be connected to a liquid reservoir and an outlet (6) designed for discharging the heated liquid, said complementary element (3) having a heating resistor (2) disposed in order to enable the heating of liquid travelling along the channel (4).

Said channel (4) has a minimum cross-sectional liquid flow area (5 min) situated distant from said outlet (6) and within closer proximity to the outlet (6) of the channel than to the inlet (5) thereof.
LIQUID-HEATING DEVICE FOR ELECTRIC HOUSEHOLD APPLIANCE

[0001] This invention relates in general to the field of electric household appliances. More particularly, it concerns domestic appliances requiring the heating of a liquid, and more particularly the heating of water, to a temperature lower than that at which it changes to the gaseous phase. Citable among these devices are electric coffee makers, espresso machines and hot beverage dispensers, which require water to be produced rapidly, at a temperature higher than 60° and lower than the boiling temperature of the liquid.

[0002] More particularly, the invention relates to a liquid-heating device for an electric household appliance, comprising a main body associated with a complementary element covering one face of the main body, creating a liquid circulation channel between the complementary element and main body, which has two ends forming a inlet designed to be connected to a liquid reservoir and an outlet designed for discharging the heated liquid, said complementary element having a heating resistor disposed in order to enable the heating of liquid travelling along the channel.

[0003] In order to reduce the time required to heat a given quantity of liquid to a given temperature, liquid-heating device manufacturers have developed heating devices having various architectures for arranging the liquid circulation channel in relation to the heating resistor.

[0004] A liquid-heating device of the type defined above is known from the document FR-A-2 855 359, and is provided with a main body having a low thermal inertia, lower than that of aluminium. This device is particularly advantageous because, due to the low inertia thereof, the main body stores a very small amount of the heat produced by the resistor. The thermal efficiency of this heating device is thus improved while reducing heat losses.

[0005] However, at a temperature higher than 80° C. and with a normal desired water flow rate, the appearance of vapour bubbles is observed in the outlet section of the channel, which, in the long run, manages to attack the plastic material of the main body carrying the channel. The service life of the appliance is therefore sharply reduced. It is therefore necessary to use much more costly plastics technologies. Furthermore, a device such as this has a tendency to become scaled, thereby degrading the energy efficiency thereof as the operating cycles progress.

[0006] In this context, the purpose of this invention is to propose a heating device which enables at least some of the aforesaid disadvantages to be mitigated and which, in particular, has less tendency to become scaled when heating liquids to temperatures close to boiling.

[0007] To that end, the device of the invention, which is otherwise consistent with the generic definition thereof provided in the preamble set forth above, is substantially characterised in that said channel has a minimum cross-sectional liquid flow area situated distant from said outlet and within closer proximity to the outlet of the channel than to the inlet thereof.

[0008] Owing to the invention, between the minimum cross-sectional area of the channel and the inlet, the flow rate of the liquid is relatively slow, which enables the progressive heating thereof over a considerable length of the channel (at least equal to the length of the channel). Then, at the location of the minimum cross-sectional area and at with a constant flow of liquid, the flow rate of the liquid increases due to the constriction associated with the minimum cross-sectional area.

[0009] The location of the constriction formed in the channel is chosen so as to be positioned in a hot area of the channel, i.e., in proximity to the outlet thereof. It is in fact in the hot area that the vapour bubbles form and that the scale is deposited. By accelerating the velocity of the liquid in the hot area of the channel, the pressure of the liquid against the hot walls of the channel is then increased, thereby resulting in a reduction in the amount of vapour generated and/or more rapid evacuation of these vapour bubbles, which become less corrosive for the material.

[0010] Increasing the velocity of the water in the hot area of the channel is accomplished by a reduction in the amount of scale being deposited on the walls of the channel.

[0011] Furthermore, the heat exchange between the walls of the channel and the liquid is improved because there is better thermal conduction with a liquid/wall interface than with a vapour/wall interface.

[0012] Owing to the invention, the temperature at which vapour is created in the channel is increased compared to what it is in the case of a heating device which does not have any minimum cross-sectional area forming a constriction in the channel in the hot area. It is thus possible to increase the heating power of the resistor without necessarily generating more vapour than in the devices of the prior art. Consequently, the speed with which the liquid is heated can be increased without unnecessarily producing a scaling area.

[0013] For example, it can be arranged for the device to comprise a channel portion which becomes progressively constricted as it approaches the channel outlet, this constricted portion being situated within closer proximity to the outlet of the channel than to the inlet thereof, between said minimum cross-sectional liquid flow area and said channel inlet.

[0014] This progressively constricted area is intended:

[0015] on the one hand, to reduce head losses caused by the presence of the minimum cross-sectional area and;

[0016] on the other hand, to progressively increase the internal static pressure of the channel and the velocity of the liquid when approaching the minimum cross-sectional area.

[0017] Consequently, and for the same reasons as those stated above, the temperature of the progressively constricted area can, on average, be increased without necessarily creating a vapour-generating area.

[0018] For example, it can be arranged for the minimum cross-sectional area to belong to a channel portion of constant minimum cross section over the entire length thereof, this channel portion of constant minimum cross section being immediately contiguous with said constricted portion.

[0019] In this embodiment, when moving towards the channel outlet, the cross-sectional areas of the channel becomes progressively constricted along the constricted portion until becoming minimum and constant over the entire length of the channel portion of constant minimum cross section.

[0020] It is likewise possible to arrange for the heating resistor to be screen-printed onto a face of the complementary element opposite the main body. This embodiment enables optimum heat exchange between the resistor and the complementary element, thereby equally improving the efficiency of the device.
[0021] It is likewise possible to arrange for the distance
separating said minimum cross-sectional area of the channel
from the outlet to be at least one tenth of the total length of the
channel, as measured between the inlet and outlet thereof.
This embodiment makes it possible to reduce the pressure
exerted by the heated liquid on the wall of the channel in
proximity to the outlet, which is a slightly cooled area due to
the proximity of the outlet to the exterior of the device. This
widening of the cross-sectional area of the channel in prox-
imity to the outlet is designed so as to not create any area
promoting the occurrence of vapour via cavitation.

[0022] It is likewise possible to arrange for the minimum
cross-sectional area to be less than half of a maximum cross-
sectional fluid flow area in the channel, preferably less than
a quarter of this maximum cross-sectional area and preferably
less than a fifth of this maximum cross-sectional area. At a
constant temperature, the velocity of the liquid at a given
location in the channel is inversely proportional to the cross-
sectional area of the channel at that location.

[0023] Thus, provision will be made to adjust the channel
profile in order to optimise the liquid heat-up curve as it flows
through the channel, so as to prevent the liquid from passing
on to the vapour phase. In connection with this profile adjust-
ment, it was ascertained that the minimum cross-sectional
area should be at least equal to half of the maximum cross-
sectional area, and preferably equal to a fifth of this maximum
cross-sectional area, thereby making it possible to ensure
ideal conditions for carrying away possible scale particles
which might have formed along the channel in proximity to
the areas of constricted cross section.

[0024] It is also possible to arrange for the distance existing
between the complementary element and the main body, over
the entire length of the channel, to be minimal at the location
of said minimum cross-sectional liquid flow area.

[0025] This distance between the complementary element
and the main body corresponds to the depth of the channel.
The shallower the depth of the channel, the more the fluid
pressure against the complementary element will tend to
build up, thereby promoting heat exchange at this location
while preventing the creation of vapour therein.

[0026] It is likewise possible to arrange for the complemen-
tary element to be a tube inside of which the main body is
disposed, and for the channel to be in the form of a spiral
wound about the main body, the turns of which spiral closest
to one another being situated in proximity to the location
where said minimum cross-sectional area is located.

[0027] Owing to this tubular complementary element and
the spirally-shaped channel, heat losses are reduced
because of the concentric accumulation of heat towards the
interior of the complementary element. The closing in of the
spires in proximity to the location where the minimum cross-
sectional area is located is advantageous because it mechan-
ically strengthens the structure of the spiral, which is more
resistant in the hot area thereof (area situated in closer prox-
imity to the outlet than to the inlet) than in the cold area
thereof (area situated in closer proximity to the inlet than to
the outlet). This local reinforcement of the spiral structure
enables the device of the invention to heat a liquid such as
water to more than 90°C, with an operating pressure of one
bar (between 2 and 20 bars) and with a heated liquid flow rate
of the order of 500 ml/min. The capacities of the device of the
invention are above the conventional capacities of ordinary
devices used in instant beverage appliances.

[0028] Alternatively, it can be arranged for the main body to
be flat and for the channel to be in the form of a flat spiral. This
embodiment can be used for certain appliances requiring
planar heating devices due to space requirement issues. In this
embodiment, it is also possible to form the minimum cross-
sectional flow area by bringing the turns closer to one another
in order to progressively reduce the cross-sectional area of the
planar channel until reaching the minimum cross-sectional
area. The inlet to this device can be located at the centre of the
spiral and outlet at the periphery, or vice versa. At any event,
the channel should be ensured that the minimum cross-sectional area
is situated in closer proximity to the outlet than to the inlet, for
example, by modifying the relative spacing between two con-
secutive turns of the spiral and/or by modifying the depth of
the channel as stated above.

[0029] It can also be arranged for the channel to be formed
by a groove made in said main body.

[0030] Other characteristics and advantages of the inven-
tion will become apparent from the description thereof pro-
vided hereinbelow for non-limiting illustrative purposes, in
reference to the appended drawings, in which:

[0031] FIG. 1 shows an exploded perspective view of the
heating device in accordance with the invention;

[0032] FIG. 2 shows a longitudinal sectional view of the
heating device of FIG. 1;

[0033] FIG. 3 shows a longitudinal sectional view of the
single main body mounted inside the device of FIGS. 1 and 2.

[0034] As stated above, the invention relates to a liquid-
heating device. This device comprises a main body 1 of sub-
stantially cylindrical shape, and a tubular-shaped comple-
mentary element 3 holding a heating resistor 2. The main
body 1 is dimensioned to be inserted into the complementary
element 3 forming a sleeve. A leak-proof area between the
main body and the complementary element is formed at each
end of the tube 3. These leak-proof areas are visible in FIG. 2
where O-rings 12a, 12b inserted into annular grooves 13a,
13b of the main body 1 are bearing against an internal face
of the complementary element 3.

[0035] A channel 4 is formed between these leak-proof
areas and between the internal face of the complementary
element 3 and the main body 1. This channel 4 is the space
existing between the main body 1 and the complementary
element 3, and running between the inlet of the channel and
the outlet thereof. A spiral groove 10 wound about the main
body 1, along the longitudinal axis of the body, gives the
channel 4 its substantially spiral shape.

[0036] A first end of this groove 10 terminates in a first
opening forming the outlet 6 communicating with the exterior
of the device via a first tube 14a.

[0037] A second end of this groove 10 terminates in a
second opening forming the inlet 5 communicating with the
exterior of the device via a second tube 14b.

[0038] Each of these tubes 14a and 14b extends towards
the exterior of the device in order to be connected to a water
supply system for the heating appliance. The second tube 14b
is typically connected to a cold water supply reservoir and the
first tube 14a is connected to a hot water dispenser equipped
with a spigot. The fluid can flow either by gravity, by placing
the reservoir above the heating device, or by means of a forced
flow using a pump placed between the cold water reservoir
and the device 11.

[0039] The groove formed on the main body in order to
define the channel 4 has a variable depth and width, depend-
ing on the location inside the channel 4.
The channel has substantially four successive portions in the direction in which the liquid flows.

A first channel portion into which the inlet 5 opens has a maximum cross-sectional fluid flow area Smax (visible in FIG. 3). This maximum cross-sectional area is the largest along the entire length of the channel 4.

A second channel portion 7 is defined immediately downstream from the first portion, in order to enable progressive constriction of the cross-sectional fluid flow area of the channel. This second portion 7 is called the constricted portion.

A third channel portion 8 is defined immediately downstream from the second portion, in order to define a minimum cross-sectional fluid circulation area 5 min, where 5 min is the smallest cross-sectional fluid flow area along the entire length of the channel.

A fourth cross-sectional channel area immediately downstream from the third portion connects this third portion to the outlet while progressively widening the cross-sectional fluid flow area.

In terms of percentage of the total length of the channel:

1. The first channel portion accounts for between 35% and 50% of this total length;
2. The second portion accounts for between 15% and 30% of this total length;
3. The third channel portion accounts for between 15% and 40% of this total length;
4. The fourth portion accounts for between 5% and 20% of this total length.

In the case illustrated, the first portion accounts for 50% of the total length of the channel, the constricted portion 7 approximately 15% of this length, the minimum cross-sectional channel area portion 8 approximately 25%, and the fourth portion approximately 10%.

In this embodiment, the constant minimum cross-sectional flow area 5 min 4 times smaller than the maximum cross-sectional area Smax, thereby enabling the fluid velocity to be increased by a factor of 4. This makes it possible to prevent the creation of bubbles in the channel and increases the heat exchange between the liquid and the complementary element carrying the heating resistor 2. The channel is anticipated to facilitate the evacuation of bubbles which are detrimental to proper heat exchange.

In order to produce the variation in cross-sectional area inside the channel, the depth of and width of the groove are varied. Thus, at the location of the maximum cross-sectional flow area, the channel has a width of approximately 4 mm and depth Dmax of 3 mm, thereby creating a maximum cross-sectional area of 12 mm².

At the location of the minimum cross-sectional flow area, the width of the channel is approximately 1.5 mm and the depth Dmin thereof is approximately 2 mm, thereby creating a minimum cross-sectional area of 3 mm².

Between these minimum and maximum cross-sectional areas, the channel is shaped such that the width and depth thereof evolve along a regular, progressive and continuous curve, thereby reducing head losses.

As indicated previously, the screen-printed heating resistor 2 is formed on the face 9 of the complementary element 3 which is opposite the main body 1.

This resistor 2 is designed to supply an evenly distributed and uniform heating power over the entire length of the channel 4, in order to enable the liquid flowing inside the channel to heat up along the entire transit thereof. The resistor 2 heats in a substantially uniform manner over the entire length thereof.

The resistor 2 consists of two resistive circuits 2a, 2b mounted in parallel between two supply terminals 15a, 15b, which are also screen-printed. These resistive circuits are wound in spirals on the face 9 of the complementary element and terminals 15a, 15b are disposed so as to enable electrical contact with metal blades typically made of copper.

To create this resistor, one or more layers of an insulating material are screen-printed onto the complementary element, then a conductive paste in a particular pathway, and a layer for forming the supply terminals 15a, 15b, and finally one or more layers of an insulating material. The available heating power can be of the order of 2000 W.

In one preferential embodiment, the thickness of the sleeve-like complementary element is reduced to a maximum in order to promote conductive heat transfers from the resistor to the liquid in the channel. A material should be chosen for making the complementary element which has high thermal conductivity, e.g., greater than 40. Thermal conductivity (Cth) is understood to mean the ratio of the value of the coefficient of thermal conductivity (X) of the material of the complementary element divided by the value of the thickness (e) thereof expressed in millimetres.

Cth = X / e.

In other words, the complementary element transmits heat energy from the heating resistor to the liquid very quickly, because the thickness thereof is very small, of the order of 1 to 3 millimetres, and because the constituent material thereof, which is aluminium, copper or stainless steel, has a high degree of thermal conductivity.

In one preferential embodiment, the main body is made of a plastic material, or more generally speaking of a material having low thermal inertia l, which, at any event, is lower than that of aluminium, which is of the order of 2.30, so as to store only a small portion of the heating energy. Materials that can be cited as likely to be well-suited to the production of the main body 1 of the invention include polyamide (l = 1.9), polyacetal (l = 2), polypropylene (l = 1.6), polysulphone (l = 1.4) or polycarbonate (l = 1.5).

Owing to the invention, the hot area of the main body, which is a critical design area, is rendered mechanically stronger due to the small width of the channel and the greater surface density of the groove-forming blades. It is to be noted that these blades can be wider in the hot area, in proximity to the channel outlet, than in the rest of the device. This novel channel shape likewise enables improved heat exchange with the channel water and therefore noticeable cooling of the main body in the hottest area.

Consequently, the main body, which is generally made of mechanically strong but costly food-grade PPS, can now be made of a filled polyamide, the mechanical strength of which is lower but the cost of which is less.

A temperature sensor 16, such as a thermistor, visible in FIG. 1, is advantageously attached to the face 9 of the complementary element, and is hooked up to an electronic circuit by means of two terminals 16a, 16b. This electronic circuit controls the electric power supply to the resistive tracks, whereby the complementary element is kept at a predetermined temperature when the water is circulating.

In one particular embodiment, it is possible to arrange for a fusible area to be created in the resistor, at the
surface of the complementary element. In this way, in the event that the resistor overheats, the fusible area melts, thereby interrupting the power supply to the resistor and cutting off the heat.

[0666] Typically, the user turns on the heating device with an operating control, which causes the liquid to begin circulating inside the channel and the resistor to heat up. Owing to the invention, the temperature increase slope inside the channel is of the order $30^\circ$ C per second versus $5^\circ$ C per second as measured on certain devices of the prior art. Thus, the heating device is preheated very quickly and the liquid heated to between $80$ and $90^\circ$ C can be reliably delivered within a few seconds, by regulating the liquid flow rate and the heating power.

1. Liquid-heating device (11) for an electric household appliance, the device comprising a main body (1) and a complementary element (3) disposed opposite a face of the main body (1), a liquid circulation channel (4) existing between the complementary element (3) and main body (1), said channel having two ends forming an inlet (5) designed to be connected to a liquid reservoir and an outlet (6) designed for discharging the heated liquid, said complementary element (3) having a heating resistor (2) disposed in order to enable the heating of liquid travelling along the channel (4), characterised in that said channel (4) has a cross-section defined in depth by the main body (1) and the complementary element (3) and defined in width by at least a blade extending from the main body (1) to the complementary element (3), said channel (4) having a minimum cross-sectional liquid flow area (5 min) situated distant from said outlet (6) and within closer proximity to the outlet (6) of the channel than to the inlet (5) thereof.

2. Device of claim 1, characterized in that it comprises a constricted channel portion situated within closer proximity to the outlet (6) of the channel than to the inlet (5) thereof, between said minimum cross-sectional liquid flow area (5 min) and said channel inlet (5).

3. Device of claim 2, characterized in that the constricted channel portion becomes progressively constricted (7) in the direction of the channel outlet (6), this constricted portion being referred to as the constricted portion (7).

4. Device of claim 3, characterized in that the minimum cross-sectional area (5 min) belongs to a channel portion of constant minimum cross section (8) over the entire length thereof, this channel portion of constant minimum cross section (8) being immediately contiguous with said constricted portion (7).

5. Device as claimed in claim 1, characterised in that the heating resistor (2) is screen-printed onto a face (9) of the complementary element (3) opposite the main body (1).

6. Device as claimed in claim 1, characterised in that the distance separating said minimum cross-sectional area of the channel from the outlet to be at least one tenth of the total length of the channel, when measured between the inlet (5) and outlet (6) thereof.

7. Device as claimed in claim 1, characterised in that the minimum cross-sectional area (5 min) is less than half of a maximum cross-sectional fluid flow area ($S_{\text{max}}$) in the channel, preferably less than a quarter of this maximum cross-sectional area ($S_{\text{max}}$) and preferably less than a fifth of this maximum cross-sectional area ($S_{\text{max}}$).

8. Device as claimed in claim 1, characterised in that the distance existing between the complementary element (3) and the main body (1), over the entire length of the channel, is minimal ($D_{\text{min}}$) at the location of said minimum cross-sectional liquid flow area (5 min).

9. Device as claimed in claim 1, characterised in that said complementary element (3) is a tube inside of which the main body (1) is disposed, and in that the channel (4) is in the form of a spiral wound about the main body (1), the turns of this spiral closest to one another being situated in proximity to the location where said minimum cross-sectional area (5 min) is located.

10. (canceled)

11. (canceled)

12. Device as claimed in claim 9, wherein the turns of the spiral closest to one another are situated in proximity to the location where said minimum cross-sectional area (5 min) is located.

13. Device as claimed in claim 1, characterised in that the main body (1) is flat and the channel is in the form of a planar spiral.

14. Device as claimed in claim 1, characterised in that the channel (4) is formed by a groove (10) made in said main body (1).

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