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(54) Method for adjusting the opening of a fluid valve, and gas cooking household appliance using it

(57) The present invention relates to a method for adjusting the opening of a valve (1) for a fluid, in particular for fuel gas, by adjusting an electric parameter, in particular voltage or current, of an electric signal (S) sent to a control input of the valve (1); in order to change the value of the electric parameter that controls the electric control signal (S) of the valve (1) from an initial value (A;D) to a final value (B;E), a variation is made such that said electric parameter has at least for an instant an intermediate value (C;F) which depends on at least said final value (B;E) and which is outside the "initial value - final value" range.

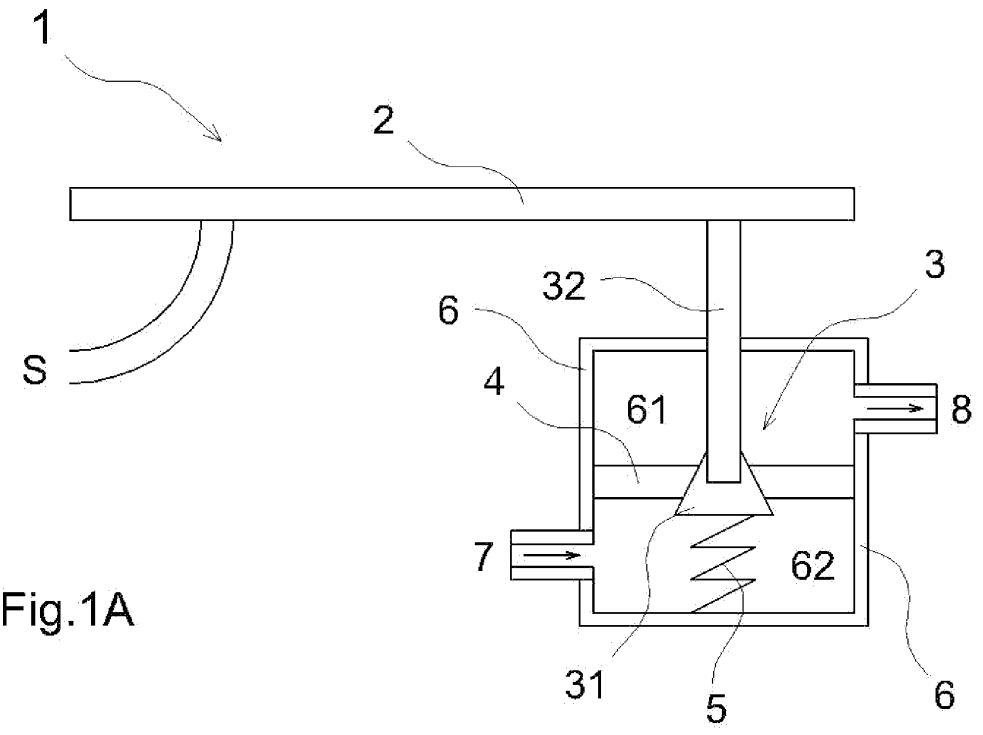


Fig.1A

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Description

[0001] The present invention relates to a method for adjusting the opening of a valve for a fluid, in particular for fuel gas, as well as to a household gas cooking appliance using such method.

[0002] Gas cooking appliances, in particular gas cooking tops, with electrically controlled valves are not widespread on the market, although this typology of household appliances is accepted by the applicable regulations.

[0003] In such household appliances, the gas supplied to a burner is adjusted through a valve having a shutter that is not controlled directly and manually by the user, but by means of an actuator controlled by electric signals, e.g. a voltage signal; by acting on a knob, a slider or push-buttons of a control panel of the household appliance, the user approximately sets the desired flame level, thus also setting indirectly the heat output of said burner; the control panel is connected to an electronic control system of the household appliance, which sends appropriate electric signals to the valve and adjusts the opening thereof so as to obtain the flame level set by the user on the burner.

[0004] Of course, it is important that a certain user setting always provides substantially the same flame level.

[0005] The Applicant realized that with many types of electrically controlled valves, in particular with piezoelectric valves, identical control signals do not always produce the same valve opening degree. In piezoelectric valves, one of the phenomena which mainly contribute to this problem is the hysteresis of the piezoelectric actuator during its movement in both directions.

[0006] Aiming at solving this problem, known adjustment methods use feedback information about the valve opening condition, based on which the control system changes the control signal in order to obtain the flame level set by the user.

[0007] However, these adjustment methods suffer from the drawback that they require special components which increase the complexity and cost of the system, thus being hardly acceptable for use in consumer products like household appliances.

[0008] The general object of the present invention is to provide a method for adjusting the opening of a valve for a fluid, in particular for fuel gas, in an accurate manner without using any feedback information, such as the valve opening condition or the quantity of gas flowing through the valve.

[0009] A first particular object of the present invention is to provide a method which can be easily implemented in general and in a gas cooking top in particular.

[0010] A second particular object of the present invention is to provide a reliable method.

[0011] A third particular object of the present invention is to provide a method which requires no modifications to the valve structure.

[0012] These and other objects are achieved by the method having the features set out in the appended claims, which are intended as an integral part of the present description.

[0013] The present invention is based on the idea of modifying the electric valve control signal according to different predefined strategies which depend on the adjustment required from time to time.

[0014] In particular, when it is necessary to change the value of the electric control parameter, in particular voltage or current, of the electric valve control signal from an initial value to a final value, a variation is made such that said electric parameter has at least for an instant an intermediate value which depends on said final value and which is outside the "initial value - final value" range. As a result, the obtained opening will be essentially always as desired.

[0015] This idea has proven to be particularly effective for those valves having an actuator subject to motion hysteresis, and especially for those piezoelectric valves which are particularly suitable for use in gas cooking appliances. According to a further aspect of the present invention, it also relates to a gas cooking household appliance.

[0016] The present invention will become more apparent from the following description and from the annexed drawings, wherein:

Figs.1 show, in a very schematic manner, an electrically controlled piezoelectric valve in the closed condition (Fig.1A) and in the open condition (Fig.1B),
Fig.2 shows a diagram relating to a first example of embodiment of the adjustment method according to the present invention,
Fig.3 shows a diagram relating to a second example of embodiment of the adjustment method according to the present invention,
Fig.4 shows an example of a diagram for the calculation of an asymptotic voltage for compensating for variations in the opening of a valve occurring over time,
Fig.5 shows the trend of a variation of the control voltage of a valve produced in order to compensate for variations in the opening of the valve occurring over time,
Fig.6 shows five trends of the temperature of a burner over time, and
Fig.7 shows the trend over time of five variations in the control voltage of a valve produced in order to compensate for valve opening changes due to temperature.

[0017] Said description and said drawings are to be considered as non-limiting examples.

[0018] In Fig.1, the valve is designated as a whole by reference numeral 1.

[0019] Reference numeral 2 designates a piezoelectric element acting as an actuator of an adjuster device 3 of the valve 1; reference numeral 31 designates the

shutter of valve 1, belonging to adjuster device 3; reference numeral 32 designates a stem belonging to adjuster device 3 of valve 1. Shutter 31 and stem 32 are rigidly joined together, thus forming adjuster device 3, which is pushed by actuator 2.

[0020] Actuator 2 receives an electric signal S through two electric leads; actuator 2 is so conceived that, when a direct electric voltage is applied as a signal S, it will bend downwards (note the difference between Fig.1A and Fig.1B) and adjuster device 3 will move downwards accordingly; the greater the amplitude of voltage signal S, the more actuator 2 will bend; actuator 2 is subject to hysteresis to motion.

[0021] The valve of Fig. 1 comprises a hollow body 6 having a gas inlet duct 7 and a gas outlet duct 8. The cavity of body 6 is divided by a rigid septum 4 into an upper outlet cavity 61 and a lower inlet cavity 62; inlet duct 7 ends in body 6, in particular in inlet cavity 62, while duct 8 starts in body 6, in particular in outlet cavity 61. Septum 4 has an aperture 40 (preferably a flared hole) allowing the gas to flow from cavity 62 to cavity 61. Shutter 31, for example having a conical shape, is adapted to shut aperture 40 of septum 4 by perfectly coupling thereto, thus ensuring tightness.

[0022] In its upper portion, body 6 of the valve of Fig. 1 has a hole which allows stem 32 to slide while at the same time preventing any substantial gas leaks from chamber 61. By way of non-limiting example, a sealing membrane (not shown in the drawing) made of an elastic material and preferably having an axially symmetrical shape, may advantageously be associated with said hole, in particular the membrane being secured to body 6 and made integral with stem 32 by applying a constraining element (e.g. an interfering profile) onto stem 32 such that said membrane is allowed to prevent any substantial gas leaks from chamber 61 whatever the position taken by stem 32.

[0023] Fig.1A shows a situation in which signal S has a null voltage value (or a value below the minimum voltage value set for the opening); in this situation, the valve is "fully closed" because shutter 31 is shutting aperture 40; this is the idle or inoperative condition of the valve.

[0024] Fig.1B shows a situation in which signal S has the maximum voltage value set to be applied; in this situation, the valve is considered to be "fully open" because shutter 31 is far below aperture 40 and therefore allows the gas to flow from chamber 62 to chamber 61 at the maximum flow rate set. Valve 1 will be more or less open depending on the voltage value of signal S (between the minimum and maximum values set).

[0025] An elastic element 5, in particular a spring, may also be provided in order to obtain or facilitate the return of valve 1 to its idle or inoperative condition; in the case shown in the example of Fig.1, the downward motion of adjuster device 3 is obtained through actuator 2, whereas the upward motion of adjuster device 3 is obtained through elastic element 5. This elastic element may show some inertia of motion which may increase over time.

[0026] As aforementioned, valve 1 will be more or less open depending on the voltage value of signal S; this means that the opening degree of the valve will change as the voltage value is changed.

[0027] At least one nominal characteristic curve can be defined for each valve, which curve does not take into account any hysteresis phenomena and binds the opening of the valve to the value of the electric parameter that controls the electric control signal of the valve itself; the present invention assumes that the adjustment of the opening of the valve is carried out on the basis of such a characteristic curve.

[0028] In order to illustrate in detail the adjustment method according to the present invention, it will now be assumed (without any limitations) that the control parameter of the valve control signal is the valve electric voltage, and reference will be made first to Fig.2, which shows a first example of embodiment of the invention.

[0029] This figure shows two curves T1 and T2: an upper curve T1 to be used when the control voltage must be increased, and a lower curve T2 to be used when the control voltage must be decreased. In this diagram, X axis and Y axis represent voltages expressed in "Volts"; Y axis (vertical) shows the voltage supplied to the valve control input, whereas X axis (horizontal) shows the voltage of the aforementioned nominal characteristic curve.

[0030] Let us now assume that the desired adjustment is such that the voltage value of electric control signal S supplied to the valve control input is changed from an initial value corresponding to point A to a final value corresponding to point B; as shown in the diagram, the final voltage (approx. 240 Volt) is higher than the initial voltage (approx. 150 Volt). In this case, the variation of the control voltage to be applied to the valve control input is obtained by following the broken trajectory that connects point A to point B by passing through the intermediate point C located on curve T1 right above point B; the control voltage at point C (approx. 280 Volt) is higher than the control voltage at the final point B and outside the control voltage range A-B (150-240 Volt), and it does not depend on the control voltage at the initial point A, but solely on the control voltage at the final point B as well as, of course, on the trend of curve T1. Curve T1 can be expressed by means of a mathematical function which, in the case of the example of Fig.2, will be

$$-0.0065\,X^2 + 3.38\,X - 135$$

[0031] Let us now assume that the desired adjustment is such that the control voltage value is changed from an initial value corresponding to point D to a final value corresponding to point E; as shown in the diagram, the final voltage (approx. 140 Volt) is lower than the initial voltage (approx. 220 Volt). In this case, the variation of the control voltage to be applied to the valve control input is obtained by following the broken trajectory that connects point D

to point E by passing through the intermediate point F located on the curve T2 right under point E; the control voltage at point F (approx. 90 Volt) is lower than the control voltage at the final point E and outside the control voltage range D-E (140-220 Volt), and it does not depend on the control voltage at the initial point D, but solely on the control voltage at the final point E as well as, of course, on the trend of curve T2. Curve T2 can be expressed by means of a mathematical function which, in the case of the example of Fig.2, will be

$$0.0065\ X^2 - 1.25\ X + 139$$

[0032] By appropriately choosing either one or both of the upper and lower curves, the opening of the valve will be essentially always as desired. These curves can be obtained experimentally and stored, either analytically or in table form, into the electronic control system of the household appliance, and then read and used in order to adjust the valves thereof.

[0033] The time required for going from point A to point B (through point C) and for going from point D to point E (through point F), and therefore for obtaining the variation of the valve control voltage, is not a critical factor of the present invention; however, it should be neither too short, in particular it should be longer than 1mS, preferably longer than 10mS, nor too long, in particular it should be shorter than IS, preferably shorter than 100mS. The control voltage variation speed may be either constant, like the one provided by the charge/discharge of a constant-current capacitor, or variable, like the one provided by the natural charge/discharge of a capacitor over a resistor.

[0034] Though not shown in Fig.2, it is advantageous (since it allows to stabilize the opening of the valve when the adjustment is complete) that the trajectory from the initial point to the final point passes through at least two intermediate points. The first intermediate point lies in a predetermined curve, as explained above. The second intermediate point follows (in time) the first intermediate point; in the case of the trajectory from A to B, the valve control voltage value of the second intermediate point is lower than the control voltage value corresponding to the final point B (approx. 240 Volt), in particular it is lower than the latter by a constant amount, preferably 1-10 Volt; in the case of the trajectory from D to E, the valve control voltage value of the second intermediate point is higher than the control voltage value corresponding to final point E (approx. 140 Volt), in particular it is higher than the latter by a constant amount, preferably 1-10 Volt.

[0035] The valve adjustment may be continuous or, preferably, it may be accomplished through a discrete number of adjustment points, in particular from a minimum number of three to a maximum number of nine. In fact, when the user acts on the control panel of the household appliance, he/she will find it easier to choose among a limited number of available predefined flame level settings, without any significant loss in terms of adjustment effectiveness for food cooking. Furthermore, since the adjustment is carried out through an electronic control system that typically comprises a microcontroller, a discrete type adjustment proves to be particularly suited to such a system.

[0036] A second example of embodiment of the present invention will now be illustrated with reference to Fig.3.

[0037] Fig.3 is similar to Fig.2 and shows the same two curves T1 and T2: however, the trajectory followed in order to go from point A to point B is different (although it still passes through the intermediate point C): the path leading from A to C is a more complex one; this trajectory corresponds, in particular, to A→K→L→M→N→C→B; in particular, this trajectory passes through two adjustment points, i.e. L and N. It is worth pointing out that the example of Fig.3 may refer to a discrete adjustment carried out by using just four adjustment points (A, B, L, N).

[0038] The variation of the control voltage according to the example of Fig.3 includes a plurality of increase periods in which the valve control voltage value is increased (sections A-K, L-M, N-C) and a plurality of decrease periods in which the valve control voltage value is decreased (sections K-L, M-N, C-B); the increase and decrease periods follow each other according to an alternate pattern. Moreover, said variation includes a plurality of reversal instants (points K, L, M, N, C) at which the direction of the variation of the valve control voltage is changed. The reversal instants may correspond to valve control voltage values chosen among a predefined set of values.

[0039] The above technical teachings, i.e. the use of a plurality of increase and decrease periods and the passing through a plurality of adjustment points may advantageously be used not only for going from an initial adjustment point corresponding to a lower voltage to a final adjustment point corresponding to a higher voltage (as in Fig.3), but also for going from an initial adjustment point corresponding to a higher voltage to a final adjustment point corresponding to a lower voltage (e.g. in order to switch from point D to point E of Fig.2).

[0040] For properly adjusting the opening of a valve for a fluid, in particular for fuel gas, it is advisable to take two additional and distinct technical problems into consideration:

- the (slow) modification of the opening of the valve as opening time goes by,
- the (slow) modification of the opening of the valve due to temperature variations (this problem is particularly felt during the operation of gas cooking household appliances; in fact, in this case the valve and/or fluid, in particular fuel gas, are heated by the combustion heat produced by the burners).

[0041] Some solutions to these two problems will be proposed below; of course, such solutions may be com-

bined with one another as well as, most advantageously, with the adjustment solutions described above. It should be underlined that each of said solutions may per se be an independent inventive solution.

[0042] In order to compensate for the modification of the opening of the valve as opening time goes by, it is conceivable to change the value of the electric parameter that controls the electric valve control signal according to a predetermined variation after said electric parameter has reached its final value (for example, said variation may be determined based on a nominal characteristic curve of the valve). Said predetermined variation may in particular have an asymptotic exponential trend and be proportional, in particular directly proportional, to said final value.

[0043] Fig.4 shows an example of a diagram that relates an asymptotic voltage to the final valve control voltage; this diagram is linear, but may also have a different trend. Fig.5 shows an example of an asymptotic exponential trend in the case where the asymptotic voltage obtained from Fig.4 is 6.5 Volt; ordinates are expressed in Volts, while abscissas are expressed in seconds. Let us assume, for example, that the user has set a flame level that corresponds to a final valve adjustment voltage of 215 Volt; the electronic control system of the household appliance will determine a voltage variation such that the control voltage eventually supplied to the valve will be exactly 215 Volt. In order to compensate for variations of the opening of the valve, and therefore of the flame level, as opening time goes by, it will be necessary to determine a further variation of the control voltage; in order to determine such a variation according to the embodiment example described herein, reference will be made to the graph of Fig.4 in order to find the asymptotic voltage corresponding to 215 Volt: this value is +6.5 Volt. The asymptotic voltage is used as a multiplying factor of an asymptotic exponential function starting from zero and ending at +1 with a time constant of 100-500S. Therefore, in the case corresponding to the variation shown in Fig. 5, in which the asymptotic voltage has a value of +6.5 Volt, the voltage of the electric valve control signal will be brought at first to 215 Volt in a rather short time and then, in a rather long time (e.g. 1,000 seconds), to 215+6.5 Volt.

[0044] In order to compensate for the modification of the opening of the valve due to temperature, it will possible, at least for a predetermined time (in particular for the first 1,000 or 2,000 or 3,000 seconds), to estimate or detect the temperature (e.g. of the valve or burner) and to correct the value of the electric parameter that controls the electric valve control signal according to the estimated or detected temperature; such an estimation or detection may be either continuous or repeated. In particular, in order to compensate for the modification of the opening of the valve due to temperature, it is possible to correct the value of the electric parameter of the electric control signal supplied to the valve by adding to the theoretical value a predetermined corrective value which is variable over time, in particular according to a substantially asymptotic exponential trend starting from zero (because the initial temperature is ambient temperature), e.g. like the one shown in Fig.7. Said corrective value may be proportional to the final value of the valve adjustment voltage (determined, for example, on the basis of a nominal characteristic curve of the valve), e.g. like the one shown in Fig.7.

[0045] Fig.6 shows a number of curves for different values of the final adjustment voltage (120, 140, 170, 200 and 250 Volt, respectively), which represent the change in temperature over time; ordinates are expressed in Celsius degrees, while abscissas are expressed in seconds/20 (after approx. 20x150=3,000 seconds, the temperature remains substantially constant). Fig.7 shows a number of curves for different values of the final adjustment voltage (120, 140, 170, 200 and 250 Volt, respectively), which represent the time-variable corrective value corresponding to the curves of Fig.6; ordinates are expressed in Volts, while abscissas are expressed in seconds/20 (after approx. 20x150=3,000 seconds, the corrective value remains substantially constant).

[0046] The teaching of the present invention allows to obtain, in particular, an accurate, reliable and simple adjustment of the valve used for adjusting the fuel gas supplied to a burner of a cooking household appliance, in particular comprising a cooking top or an oven; consequently, it is possible to obtain an accurate, reliable and simple adjustment of the flame level on the burner and of the heat provided by the burner without using any feedback information such as the valve opening condition or the quantity of gas flowing through the valve.

[0047] The household appliance according to the present invention typically comprises a control panel allowing the user to set the flame level of one or more burners and possibly to display the set flame level; therefore, the control panel will be connected to an electronic control system adapted to control the burner valves electrically in order to adjust the opening thereof.

[0048] The present invention has been described herein with reference to particular embodiment examples, but it is clear that many changes may be made thereto by those skilled in the art, and that all such changes will still fall within the scope defined by the appended claims. In particular, the gas cooking household appliance according to the present invention may be a gas cooking top, or a gas oven, or a gas cooker (the term "gas cooker" referring to a household appliance incorporating a gas cooking top and one or two gas-heated oven cavities), and may be either a stand-alone unit or built-in unit. Furthermore, in the case where the household appliance according to the present invention comprises a gas cooking top, said cooking top may include one or more gas burners (preferably two to six gas burners), each of which may be of any type (e.g. cup type, horizontal Venturi type, vertical Venturi type, double crown and double adjustment type, like the one described in patent application WO2006/051368, or with a semi-per-

meable flame divider, like the one described in patent application WO2007/036772, and so on).

Claims

1. Method for adjusting the opening of a valve (1) for a fluid, in particular for fuel gas, by adjusting an electric parameter, in particular voltage or current, of an electric signal (S) sent to a control input of said valve (1), **characterized in that,** in order to change the value of said electric parameter from an initial value (A) to a final value (B) higher than said initial value (A), a variation is made such that said electric parameter has at least for a first instant a first intermediate value (C) which is higher than said final value (B) and which depends on at least said final value (B).

2. Method according to claim 1, wherein said variation is such that said electric parameter has at least for a second instant, subsequent to said first instant, a second intermediate value which is lower than said final value (B) and which depends on at least said final value (B).

3. Method for adjusting the opening of a valve (1) for a fluid, in particular for fuel gas, by adjusting an electric parameter, in particular voltage or current, of an electric signal (S) sent to a control input of said valve (1), **characterized in that,** in order to change the value of said electric parameter from an initial value (D) to a final value (E) lower than said initial value (D), a variation is made such that said electric parameter has at least for a first instant a first intermediate value (F) which is lower than said final value (E) and which depends on at least said final value (E).

4. Method according to claim 3, wherein said variation is such that said electric parameter has at least for a second instant, subsequent to said first instant, a second intermediate value which is higher than said final value (E) and which depends on at least said final value (E).

5. Method according to one of the preceding claims, wherein said first intermediate value (C;F) is not dependant on said initial value (B;E).

6. Method according to one of the preceding claims, wherein said intermediate value (C;F) depends on said final value (B;E) according to a mathematical function.

7. Method according to one of the preceding claims, wherein the difference between said second intermediate value and said final value (B;E) is fixed and predetermined.

8. Method according to any of the preceding claims, wherein said variation lasts for a time ranging between 1mS and 1S, and preferably between 10mS and 100mS.

9. Method according to one of the preceding claims, wherein said initial value (A;D) and said final value (B;E) are chosen among a predefined set of values.

10. Method according to one of the preceding claims, wherein said variation includes a plurality of increase periods (AK, LM, NC) in which the value of said parameter is increased, and a plurality of decrease periods (KL, MN, CB) in which the value of said parameter is decreased, said increase and decrease periods following each other according to an alternate pattern.

11. Method according to claim 10, wherein said variation includes a plurality of reversal instants (K,L,M,N,C) at which the variation direction is reversed, said reversal instants corresponding to values of said parameter chosen among a predefined set of values.

12. Method according to one of the preceding claims, wherein, in order to compensate for the modification of the opening of said valve (1) occurring over time, once said electric parameter of said electric signal (S) has reached said final value, the value of said electric parameter is changed according to a predetermined variation, in particular according to an asymptotic exponential trend.

13. Method according to claim 12, wherein said predetermined variation is proportional, in particular directly proportional, to said final value.

14. Method according to one of claims 1 to 13, wherein, at least for a predetermined time, the temperature is estimated or detected and the value of the electric parameter of said electric signal (S) is corrected according to the estimated or detected temperature.

15. Method according to one of claims 1 to 13, wherein, in order to compensate for the modification of the opening of said valve (1) due to temperature, the value of the electric parameter of said electric signal (S) is corrected by adding a predetermined corrective value which is variable over time, in particular according to a substantially asymptotic exponential trend.

16. Method according to claim 15, wherein said corrective value is proportional to said final value.

17. Method according to any of the preceding claims, wherein said final value of said electric parameter of said electric signal (S) is determined on the basis of

a nominal characteristic curve of said valve (1), which relates the value of said parameter to the opening of said valve (1).

18. Gas cooking household appliance, comprising a burner and at least one valve (1) for adjusting the gas flow to said burner, and an electronic control system adapted to control said valve (1) electrically, **characterized in that** said electronic control system is adapted to control said valve (1) electrically in such a way as to implement the adjustment method according to any of claims 1 to 17.

19. Gas cooking household appliance according to claim 18, wherein said valve is a piezoelectric one.

20. Gas cooking household appliance according to claim 18 or 19, said gas cooking household appliance being a gas cooking top, or a gas oven, or a gas cooker.

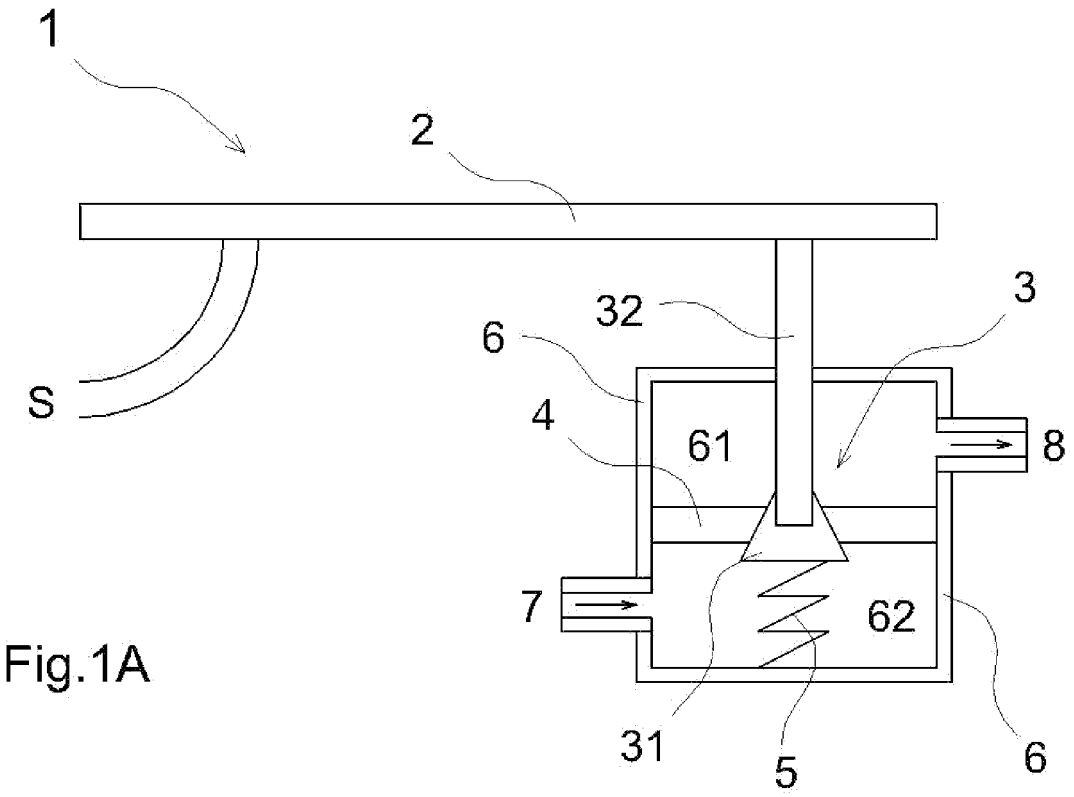


Fig.1A

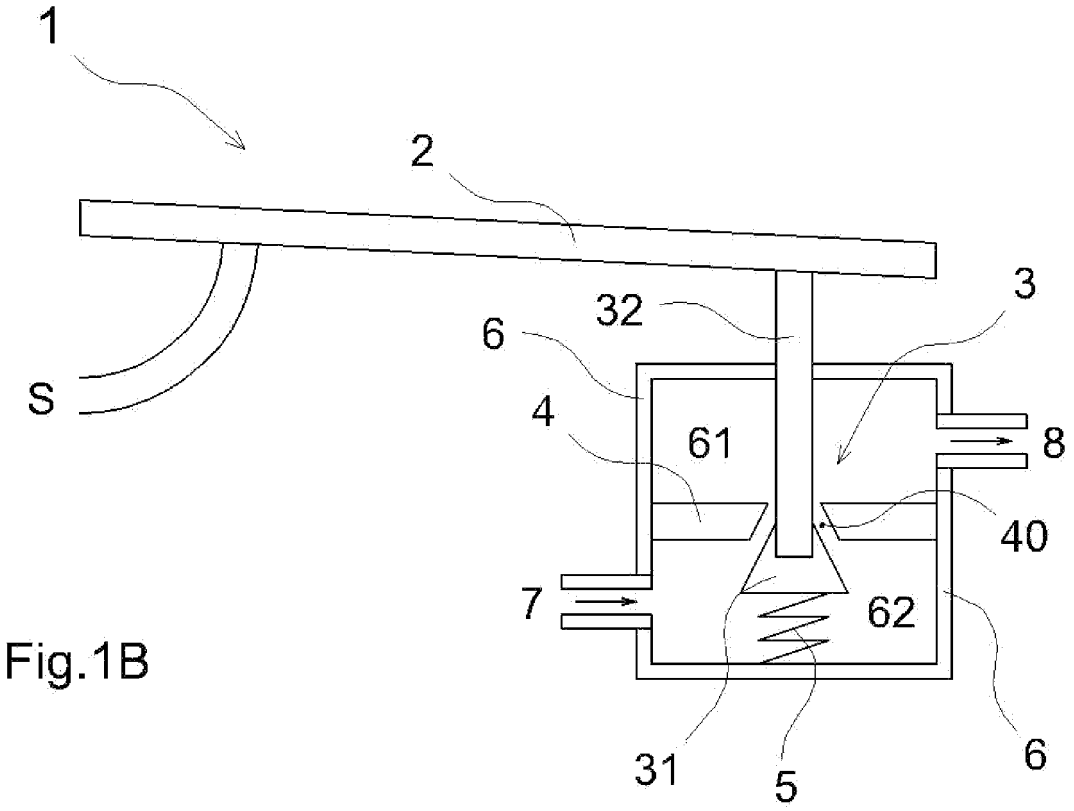


Fig.1B

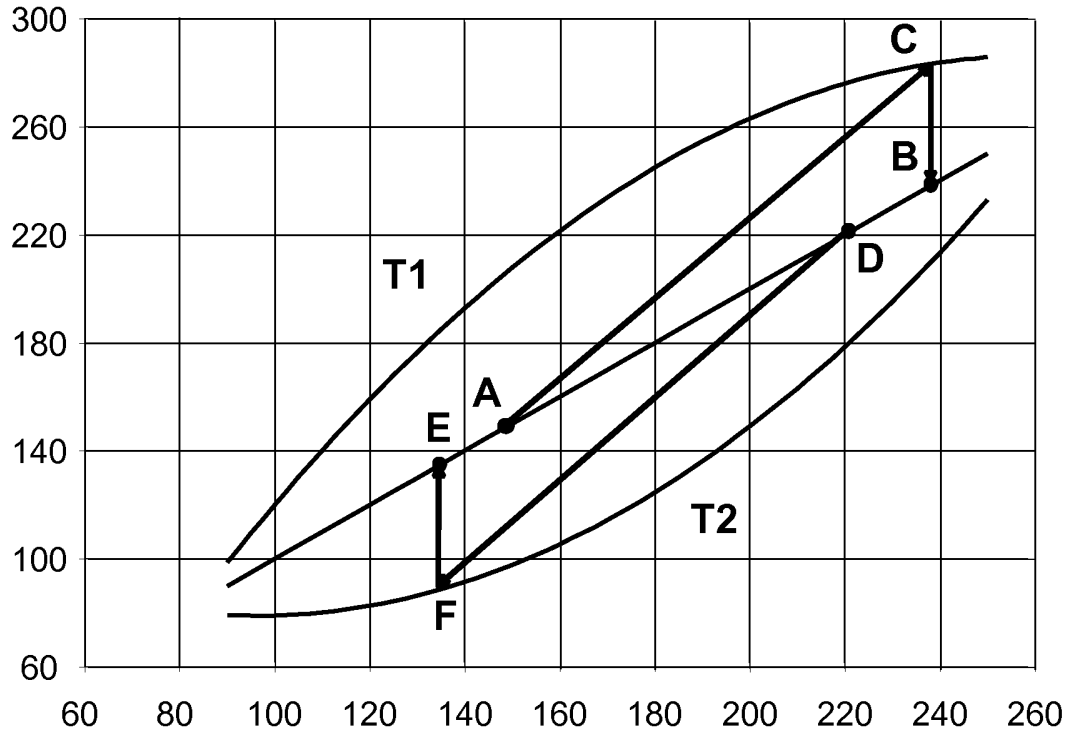

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Fig.2

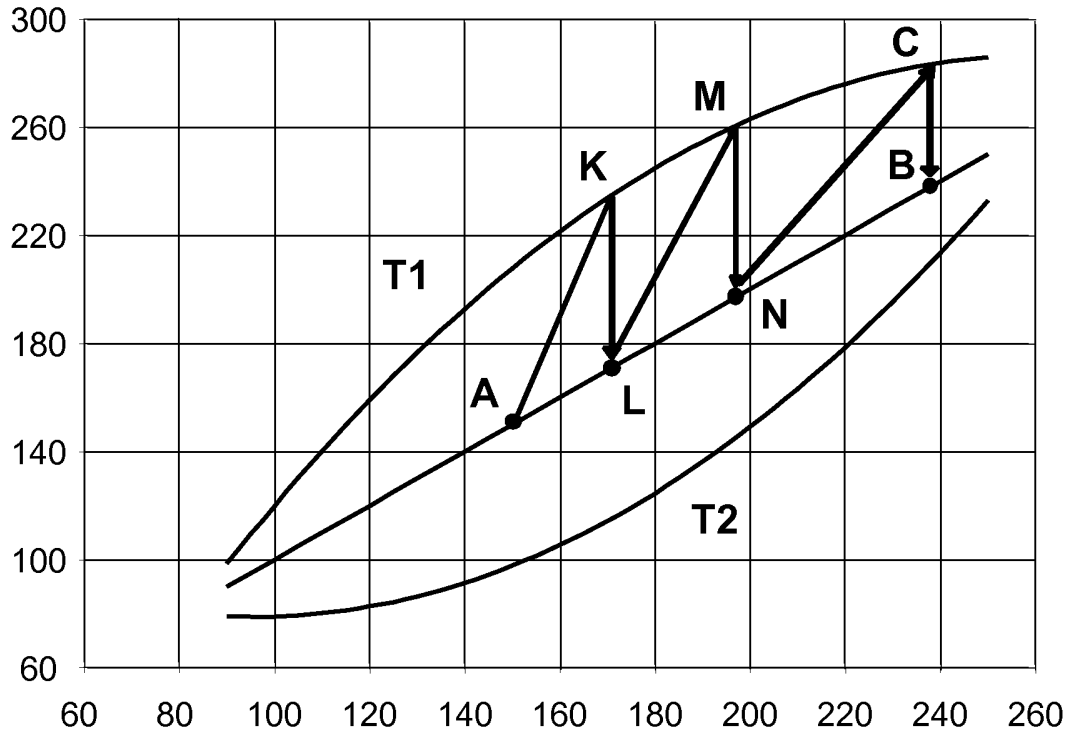

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Fig.3

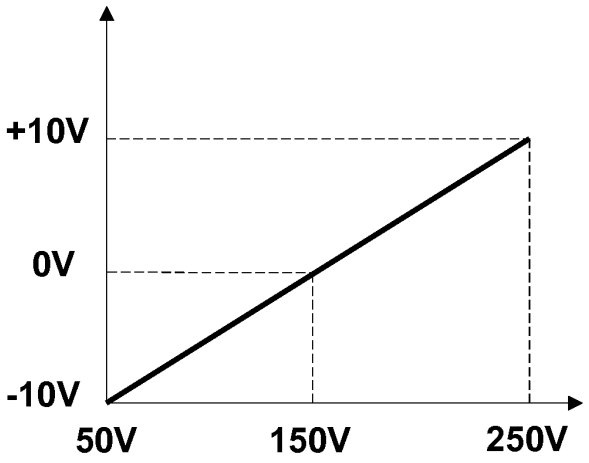


Fig.4

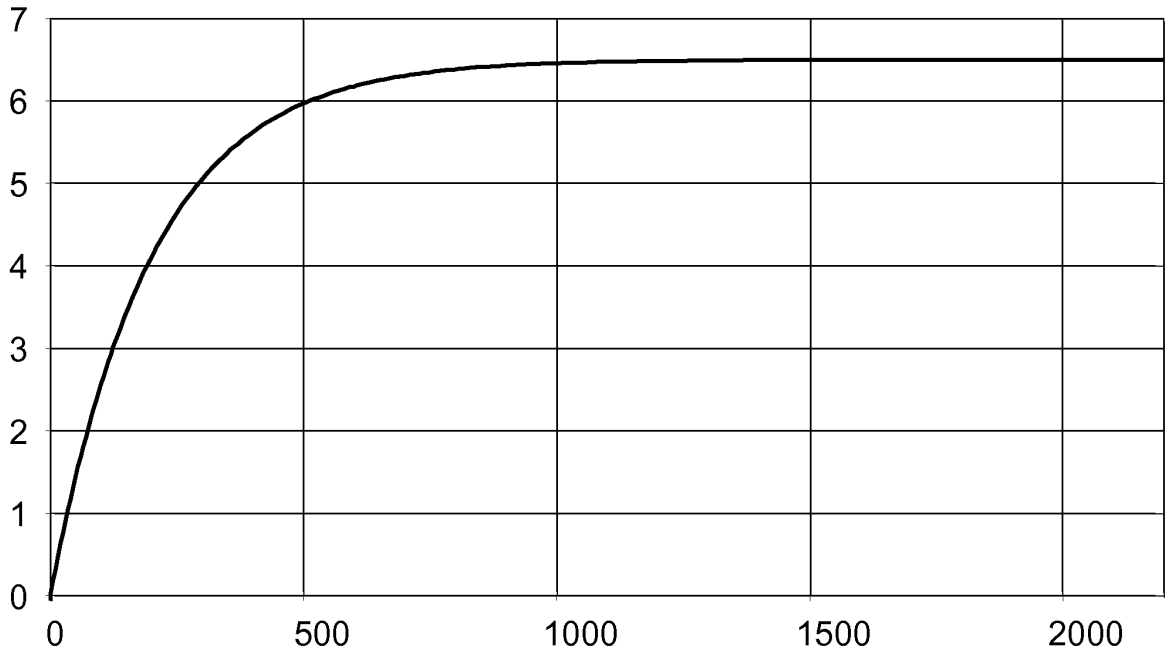


Fig.5

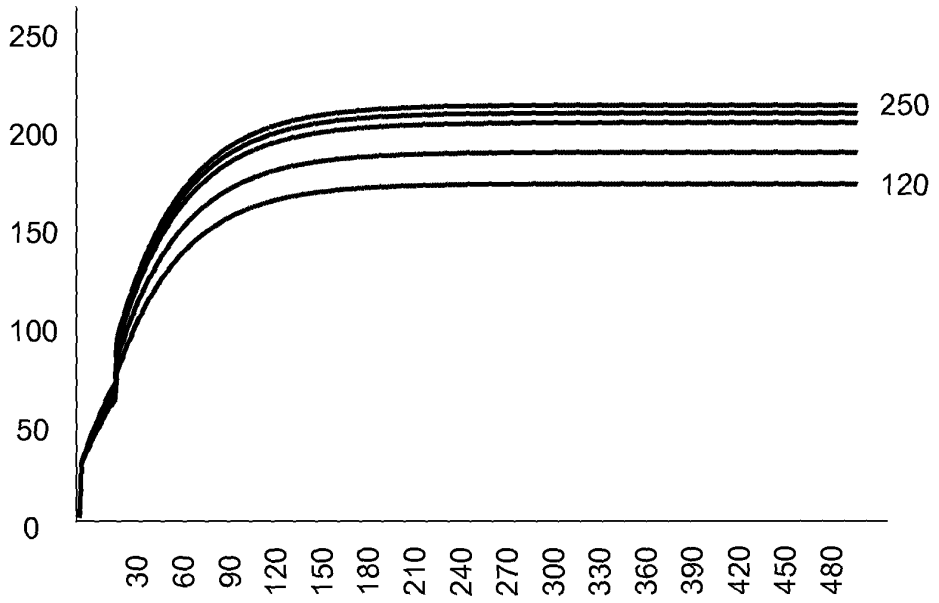

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120

Fig.6

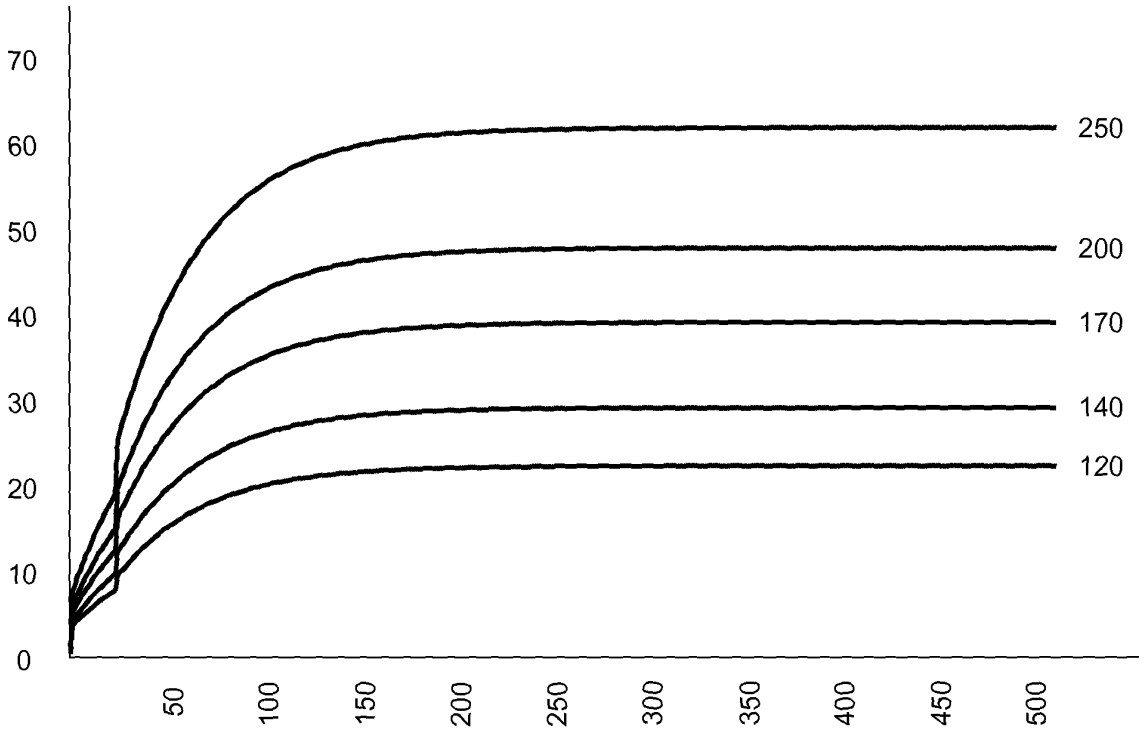

70
60
50
40
30
20
10
0
50
100
150
200
250
300
350
400
450
500
250
200
170
140
120

Fig.7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2006051368 A **[0048]**
- WO 2007036772 A **[0048]**