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(54) Controlling and checking safety aspects of heating systems for liquids utilizing electric heating elements as sensor

(57) The electronic system comprises a microcontroller which provides for the automatic temperature adjustment of solids or liquids, with the heating element being utilized as temperature sensor. Depending on the number of available heating elements, the electronic circuit is expanded with a basic circuit which is built up from two relays with make-and-break contacts by means of which the heating element can be employed for the original purpose or can be connected as a temperature sensor in a measuring bridge. Due to extensive continuous test activities by the microcontroller, the realized system design is very well protected against uncontrolled heating. Also malfunctions in the microcontroller cause the heating activities to be stopped immediately. This renders an excess temperature cutout switch redundant. Due to the alternating switching order, the two relays are loaded equally over time, which prolongs their lives significantly. The number of switching actions is further limited by performing a number of measurements during heating, so that it can be calculated after how much time the desired temperature will be reached. Just before this time has passed, a small number of measurements are carried out to achieve the final temperature within the desired tolerance. The electronic system makes both the conventional temperature sensor and the heat content sensor redundant. Further, the electronic system can measure the thickness of lime deposition on the heating elements and, depending on the measurement, give a service alarm or cut out the appliance completely.

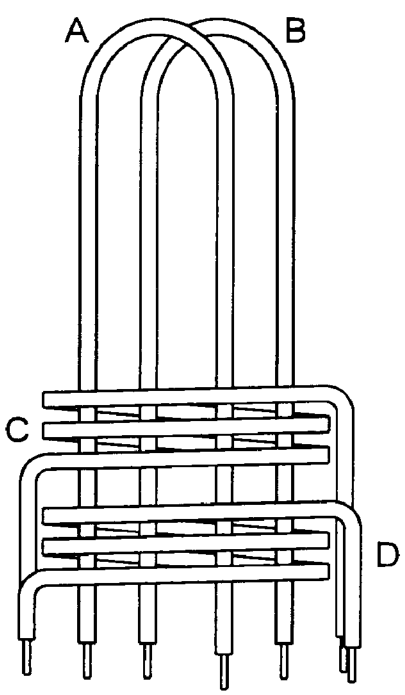

Fig. 3

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Description

[0001] This invention relates to an electronic microcontroller-controlled system by means of which the temperature of liquids (mostly water) and solids, the heat content of a particular volume of liquid, the lime deposition on electric heating elements, defects of heating elements, and the erroneous setting into operation of heating elements can be determined, with the heating elements used in the appliance or system being utilized as temperature sensors. By the use of a microcontroller within an electronic circuit designed especially for this purpose, the control is integrally safe.

[0002] In present-day appliances and systems in which liquids (mostly water) are to be heated, temperature sensors made especially for that purpose are used.

[0003] The appliances referred to include, by way of example, domestic appliances such as, for instance, electric boilers, water heaters, coffee-makers, washing machines, dishwashers, and the like.

[0004] In many designs of these appliances, use is made of a thermostatic switch or thermostatic control, the operation of which is based on the coefficient of cubic expansion of liquids. To that end, a small reservoir is mounted in a tube, which is disposed in the environment to be heated. Via a capillary tube, the reservoir is connected with a second reservoir having on one side a readily movable membrane. By heating the first-mentioned reservoir, as a result of expansion, the volume of the second reservoir increases. When the membrane has undergone a particular predetermined displacement, a mechanically coupled electrical switch goes from the conducting state (closed contacts) into the non-conducting state. This switching occurs at a temperature which is adjustable by a rotary knob which is mechanically coupled with the switch mentioned. Thus, when the desired temperature is reached, the current to the heating elements is interrupted. After the temperature has fallen, the thermostatic switch mentioned reaches the point where it switches back to the conducting state again. In this way, the temperature can be maintained within particular limits.

[0005] In most appliances, an excess temperature protection is incorporated, often in combination with the above-mentioned thermostatic control, which functions in substantially the same manner. This excess temperature protection has its own independent liquid reservoir, capillary and switching system. In the factory, the desired switching temperature has been set and fixed at a high, though still just acceptable value. When through failure of the thermostatic switch the temperature becomes too high, the excess temperature protection will interrupt the voltage supply. The current supply can be restored only by depressing a reset button on the excess temperature protection after the temperature has fallen sufficiently.

[0006] At present, in the kinds of appliances referred to, often electronic control systems are incorporated. The electronics in these appliances obtain the information about the prevailing temperature through sensors such as PTC's and NTC's (resistors with a particular positive or negative temperature coefficient as a function of the temperature). The outputs of the electronics are then equipped with relays or triacs to control the heating elements. An electronic control is capable of achieving and maintaining the desired temperature more accurately. Further, electronic controls offer more convenience to the user. In these controls, often a microprocessor is used which communicates with the user via a display and push buttons. Despite the electronic control referred to, in connection with safety requirements (EN 60335-2-21) in most cases use is made of the above-described mechanical excess temperature protection which in case of failure interrupts all phases used of the electricity grid.

[0007] In electric boilers, mostly use is made of the cheaper night-tariff current supply. The desired final temperature of the water in the boiler is set by the user or the installer. A temperature often used is 60°C. In practice, a boiler can be set at a temperature between 35°C and 85°C, which can be reached overnight. When tapping hot water which has reached a particular temperature during the nightly heating phase, this water will flow out at the top of the vessel through a tube and be replaced at the bottom of the vessel by cold influent water. At the top of the vessel, hot water will then be present (in well-insulated boilers, a temperature fall of maximally 1 Kelvin per 24 hours will occur), while at the bottom of the vessel relatively cold water will be present. Due to the manner in which cold water flows in, a sharp transition (1-2 cm) from cold to hot water will be maintained.

[0008] The present-day boilers of more deluxe design are fitted, on the outside of the vessel, with a heat content sensor, mostly consisting of a number of temperature-dependent resistors, by means of which it can be determined approximately at what height the transition from hot to cold water is located. Since the temperature of the water above the transition layer mentioned is also known, the heat content of the boiler can be determined by the electronics. Often, the number of LED's or another indication on a display indicate how many showers or baths can still be taken when using a mixing tap set at 38°C.

[0009] The appliances according to the prior art have the following drawbacks:

1. In each case, a separate temperature sensor and (in the case of boilers) a heat content sensor need to be built in. This leads to higher costs due to additional components, cabling and additional production costs.
2. The heating elements need to be checked periodically by a service mechanic for the extent of lime scaling to ensure proper operation in the long term.
3. A heating element's becoming defective in a sys-

tem with several elements is often established indirectly in that the desired temperature is reached later due to the reduced capacity. This entails reduced convenience.

4. Inadvertent connection of an appliance or system to the mains voltage while forgetting to supply water may result in defective or impaired heating elements.

5. Mostly, a cumbersome and relatively costly mechanical excess temperature protection is needed, which likewise involves additional production costs.

[0010] The invention provides a solution for the above-mentioned drawbacks by using the heating elements themselves as temperature sensor. Not only does the new temperature measuring system enable temperature determinations and heat content determinations to be carried out, but the utilization of heating elements as sensor also enables very early determination of the extent of scaling, the defective status of a heating element, and the non-presence of water.

[0011] According to the invention, a heating apparatus for heating liquids or solids, suitable in particular for use in domestic appliances, comprising at least one electrical resistance heating element excitable by an electrical supply source and means for switching on and off the at least one heating element, is made available, which is characterized by a measuring circuit for measuring the electrical resistance of the heating element, which resistance, on the basis of the temperature coefficient of the resistance wire of the heating element, forms a measure for the temperature, to which measuring circuit a measuring voltage is applied, and a controllable switching contact device which in a first position connects the heating element with the supply source and in a second position connects the heating element with the measuring circuit.

[0012] It is noted that US 4,638,960 discloses a de-icing device for aircraft such as airplanes and helicopters, which involves the use of electric heating elements. The temperature of the parts of an airplane wing to be treated or a rotor is measured during the excitation of the heating elements, on the basis of the current flowing through the elements and the voltage prevailing across the elements.

[0013] According to the invention, on the other hand, the resistance of a heating element is measured, by contrast, during an interruption of the normal excitation.

[0014] Referring to the drawings, in the following, the invention and the principle of temperature measurement with heating elements, respectively, will be further elucidated and invented applications explained.

Fig. 1 schematically shows an example of a measuring bridge and the supply voltage to which a heating element can be connected as desired by means of the make-and-break contacts of two different relays;

Fig. 2 schematically shows an example of a basic circuit with which the make-and-break contacts in Fig. 1, by means of the two relays, can be switched and be checked for proper operation by a microcontroller;

Fig. 3 schematically shows a drawing of an example of a configuration of four heating elements such as they may be arranged at the bottom of a boiler; and

Fig. 4 schematically shows an example of the makeup of a boiler vessel in which the heating elements are accommodated at the bottom.

[0015] For the heating elements, such as shown by way of example in Fig. 3, to be used as sensor, an electronic circuit has been designed which enables this. Reference is made to Figs. 1 and 2. The basic circuit for one heating element E1 is based on two independent relays RY1 and RY2 each having one make-and-break contact ry1 and ry2. In the rest position of each of these relays, the heating element, through the rest position of the contacts ry1 and ry2, is placed electrically in a measuring bridge 1 having, in this example, resistors R_1, R_2, R_3. In the active position, i.e. the normal operating position, the heating element is connected via the relay contacts with the mains voltage V1. By means of a differential amplifier 2 connected with the measuring bridge 1, a voltage is formed which is a function of the temperatures prevailing in the heating element. The heating element is then used as a temperature-dependent resistor. This is possible because each electric heating element, like any electrical resistance element, has a temperature-dependent resistance value. The output signal P of the differential amplifier 2 is applied to an analog/digital converter 6 of the microcontroller. The electronic circuit 3 which drives the two above-mentioned relays in Fig. 2 contains a microcontroller or microprocessor 4 by means of which it is constantly monitored, per transistor T1, T2 each controlling a relay, via for instance two inputs on the microcontroller, whether the relays RY1 and RY2, as to control, are in the desired state. In addition, the electronic circuit contains a transistor T4, which interrupts the supply V2 to the relays if a control signal (a square wave) on an output of the microcontroller 4 enters a static condition. This can occur, for instance, if the microcontroller 4 enters a condition of malfunction. This can be detected via capacitor C2, resistor R7 and transistor T3. Also, in the circuit 3, it is checked at short intervals via one of the connections 10, 11, 12 of the microcontroller, whether the supply voltage for the relays corresponds with the desired condition. The proper operation of the safety cut-out function is checked at least once a day by interrupting the square-wave signal which is applied to capacitor C2 by the microcontroller 4.

[0016] To prolong the life of the relays significantly, the pull-in and release of the two relays are not effected simultaneously, but in succession, such that the order of pull-in and release is constantly changed. As a result, in each case a different relay switches the full power. The second relay then switches practically unloaded. In a practical application, the above-mentioned control of the two relays occurs with the same number as the number of heating elements used. The safety cut-out function via transistor T4 can be made of single design if the number of heating elements to be controlled is not unduly large. When a function being checked is found to be faulty, all relays are set into the rest position by the microcontroller and an alarm is given. The invention utilizes the realized possibility of performing temperature measurements with normal heating elements.

[0017] During the heating of the solid or liquid, it is possible in the manner described to determine the temperature once or a number of times during a short interruption, from which, in turn, it can be derived how long, at the power set, it will take to reach the desired final temperature, so that only at the end of the heating cycle a few more measurements are needed to adjust the final temperature within the desired tolerance. The life of the switching contacts of the relays is thereby extended.

[0018] The invention further enables the following new measuring methods:

Determining the heat content of a given volume of a liquid in a vessel.

[0019] On the basis of two principles, which supplement each other, the determination of the heat content in *inter alia* boilers can be performed without the heat content sensor referred to. The two principles of determining the heat content can be used if at least two heating elements (Fig. 3) are available, which are to be mounted at the bottom of the boiler (Fig. 4). Starting from Fig. 3, a number of embodiments are possible, the operation of which will be explained hereinbelow.

Principle 1:

[0020] In a boiler as shown in Fig. 4, given an amount of water which has been fully heated up overnight (for instance to a temperature of 60°C), the water will heat all elements A, B, C and D to 60°C. By using all elements as sensor, it can be determined during the tapping of hot water of 60°C to what level cold supply water has flowed in. If, for instance, the cold water has passed element D, the resistance of this element will have fallen to a value corresponding to the temperature of this cold water. Accordingly, by measuring the resistance of element D, the temperature of the cold water can be determined as well. The resistance of the elements A and B will also decrease because they stand in this cold water for approximately 20%. When upon further tapping of hot water the cold water rises to halfway element C, the resistance of element C will approximately have a resistance corresponding to the average temperature of the cold and the hot water. The elements A and B then stand in the cold water for approximately 50%. With the value which element C provides, as well as the resistance of the elements A and B, the heat content can be determined. If the cold water rises above the element C, but lower than the top of the elements A and B, the height of the transition between cold and hot water (and hence the heat content) can be determined only by measuring the resistance of A or B.

Principle 2:

[0021] When after the use of an amount of hot water, cold water rises above the elements A and B, for instance as indicated at level K in Fig. 4, the heat content can be determined by controlling the elements A, B and optionally C for some time (a few tens of seconds). By dissipating electrical energy, the water in contact with the elements is heated and consequently rises.

[0022] When this heated water reaches the cold/hot water transition layer K, some disturbance and turbulence will arise at the transition layer. By the supply of more and more hotter water from the lower elements, this water will move down along the wall of the boiler in Fig. 4. Element D now functions as a temperature sensor by means of which it is determined how long it takes for an increase of the temperature to be signaled. The measured time between the start of the heating phase and the signaling of the temperature increase of element D is a variable for calculating the heat content of the boiler. In simple boilers, where only the elements A and B are present, the heat content can also be determined by heating with element A and measuring with element B. Also highly suitable are versions with element A as heat source and element D as sensor. For each type of boiler it can be determined by calculations and/or measurements at what height the transition layer is located, on the basis of which the heat content can subsequently be calculated.

[0023] If measurement is to take place according to principle 2, it must be determined after each hot water withdrawal, or periodically, according to this principle 2, how large the heat content still is. Each heat demand can be signaled by each of the heating elements connected as temperature sensors through natural temperature fluctuations of the cold water flowing in. Since the system described must always be controlled by a microprocessor or microcontroller, it is possible to register the pattern of use over time, which makes it possible, when there is no signaling of water use or there is no water use, still to carry out a heat content determination. Through this method, the employment of a flow sensor can be omitted.

The manner of protecting the heating elements in case the heating elements are erroneously switched on when an appliance or system is not filled with water.

[0024] When in current designs of temperature controls of hot water appliances electrical energy is supplied to the elements while the appliance in question is not yet filled with water, these elements may become defective since the temperature will rise very quickly to unacceptable values. A temperature sensor accommodated elsewhere in the appliance would not (timely) signal this high temperature.

[0025] This invention, as stated, utilizes the possibility mentioned of using a heating element as temperature sensor. Prior to the prolonged supply of electrical energy to a heating element (Fig. 4), first the resistance of the element is measured to determine the current (water or air) temperature. Thereupon, energy is sent to the element briefly (about 1-5 seconds).

[0026] Directly after that, a resistance measurement of the element is carried out. In the case where the appliance is filled with water, the measured resistance will rapidly fall back from a particular maximum to the temperature of the water. When the appliance is not, or insufficiently so, filled with water, the heating element will not be able to get rid of the heat so fast. The measured temperature will therefore decrease much more slowly. In such a situation, the microcontroller will ensure that an alarm is given (e.g. an 'Error' LED 7 lighting up). The appliance can be re-started only after a particular time and after sufficient cooling of the heating element.

Determining the extent of lime scaling of a heating element

[0027] During the first working hours of a heating element (Fig. 3), there is not yet any lime deposition which impairs the transfer of heat to the water. The microcontroller is preferably programmed to detect, for instance during the first day at a number of temperatures during the heating phase, how fast the resistance of each element falls off after the interruption of the current. The measurement proceeds in a manner similar to that described hereinabove under 'the manner of protecting the heating elements in case the heating elements are erroneously switched on when an appliance or system is not filled with water.' This measurement at certain resistance intervals occurs after a period of a few minutes in which no heating has taken place, so that the temperature of the water is substantially the same throughout the vessel. A condition for a proper determination is that the transition layer K from cold to hot water is located above the elements, or that all the water in the appliance has the same temperature and hence there is no transition layer in the appliance. The measuring results at predetermined resistance values of the elements are stored in a non-volatile memory such as, for instance, an E^2Prom. By interpolation, the microcontroller can determine for each resistance value the rate of fall of the temperature, and hence the time constant. Periodically, for instance once a month, the measurement is automatically repeated and compared with the measured values stored in the first hours. When the temperature fall time determined by the manufacturer is exceeded, the microcontroller can give an alarm. This can be done, for instance, by having the LED 7 or another LED light up, thereby indicating that service is required. When the periodic measurement indicates that a maximum value (to be set by the manufacturer) is exceeded, the appliance can be switched off definitively. This prevents an element burning out. In this event, too, the microcontroller can provide an alarm and/or indication.

Direct signaling of a faulty heating element.

[0028] When a heating element (Fig. 3) becomes defective (electrical insulation), this is immediately noticed in that too high a voltage is measured. A short-circuit with the jacket of the heating element, if it has not been determined earlier by an external earth leakage circuit breaker, is signaled by the decrease of the resistance of the heating element in the measuring bridge. In both cases, the microcomputer can give an alarm.

Protection against overheating

[0029] The present control is highly reliable by the use of two independently controllable relays RY1 and RY2 per heating element and the ability to cut out both relays via transistor T4, and by the fact that these functions are continuously tested by the microcontroller 4, and further in that in case of a malfunction of the microcontroller the square-wave signal to transistor T4 drops out. Through this design, a separate excess temperature protection is no longer needed.

Claims

1. A heating apparatus for heating liquids or solids, in particular suitable for use in domestic appliances, comprising at least one electrical resistance heating element excitable by an electrical supply source, and means for switching on and off the at least one heating element, characterized by a measuring circuit for measuring the electrical resistance of the heating element, which resistance, on the basis of the temperature coefficient of the resistance wire of the heating element, forms a measure for the temperature, to which measuring circuit a measuring voltage is applied, and a controllable switching contact device which in a first position connects the heating element with the supply source and in a second position connects the

heating element with the measuring circuit.

2. A heating apparatus according to claim 1, characterized by an electric circuit under the control of which the heating element, via the make-and-break contacts of two independently controlled relays, can be connected as desired with a supply voltage or with a resistance measuring bridge circuit.

3. A heating apparatus according to one or more of the preceding claims, characterized in that during the heating of the solid or liquid, only temperature measurements are carried out to obtain data, so that it can be calculated how much time, given the power set, is needed to reach the desired final temperature, so that only at the end of the heating cycle a few measurements need to be carried out to adjust the final temperature within the desired tolerance, this for the purpose of prolonging the life of the contacts of the two relays.

4. A heating apparatus according to one or more of claims 2 and 3, characterized in that means are provided to cause the two relays to be switched on and off in each case in a different order for the purpose of significantly prolonging the electrical life of the relays in that each relay performs one half of the total number of switching actions under full load during the life of the electronic system.

5. A heating apparatus according to one or more of claims 2 to 4, characterized in that the microcontroller is arranged to check the relay switching actions and the operation of the electric circuit and that in the event of any failure of the microcontroller through the other electronics all relays fall back into the rest position, so that all heating elements are cut off from the supply voltage by means of two independent contacts, so that a secure safety cut-out function is guaranteed.

6. A heating apparatus according to one or more of the preceding claims, characterized in that under the control of the microcontroller the thickness of lime scale on a heating element is determined by periodically comparing the time constant of the cooling of the resistance wire in the heating element at different temperatures as determined and stored during the first working hours of the heating element, with the value measured last, so that when certain values set by the manufacturer are found, a service request signal is given or, when an absolute maximum is exceeded, the appliance or system is cut out entirely.

7. A heating apparatus according to one or more of the preceding claims, characterized in that the microcontroller is arranged to determine the heat content of a boiler by measuring, in the case where the cold/hot transition layer is still located in the area of the heating elements, which can be determined through the constant decrease of the resistance of the heating element which occurs during tapping activities, the resistance which results from the addition of the two distinct parts of the heating element which are standing in the cold part and in the hot part of the water and using same together with the known temperature of the water at the top of the boiler for calculating the heat content.

8. A heating apparatus according to one or more of the preceding claims, characterized in that the microcontroller is arranged to determine the heat content of a boiler in that, in the case where the cold/hot transition layer is located above the heating elements, which can be determined after tapping activities, which are established by the fluctuation of the resistance of the heating elements as a result of natural fluctuations of the temperature of the water flowing in during tapping, electrical energy is dissipated in a spiral element located high or in a vertical element located adjacent the middle (as A in Fig. 3), it being measured how long it takes for the temperature on another heating element connected as a temperature sensor to start to rise, which time, depending on the type of boiler, indicates at what height the transition layer is located.

9. A heating apparatus according to claims 7 and 8, characterized in that the accuracy of the heat content determination can be improved by using statistical data which have been collected during the use of the appliance.

10. An electrical device comprising a microcontroller or microprocessor serving for control, for use in a heating apparatus according to any one of the preceding claims.

11. A domestic appliance comprising a heating apparatus according to any one of claims 1 to 9.

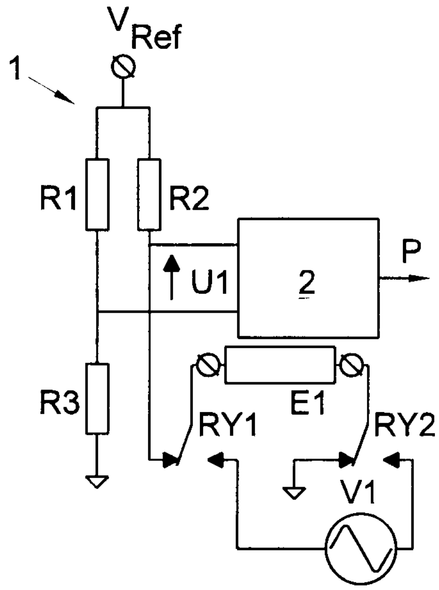

Fig. 1

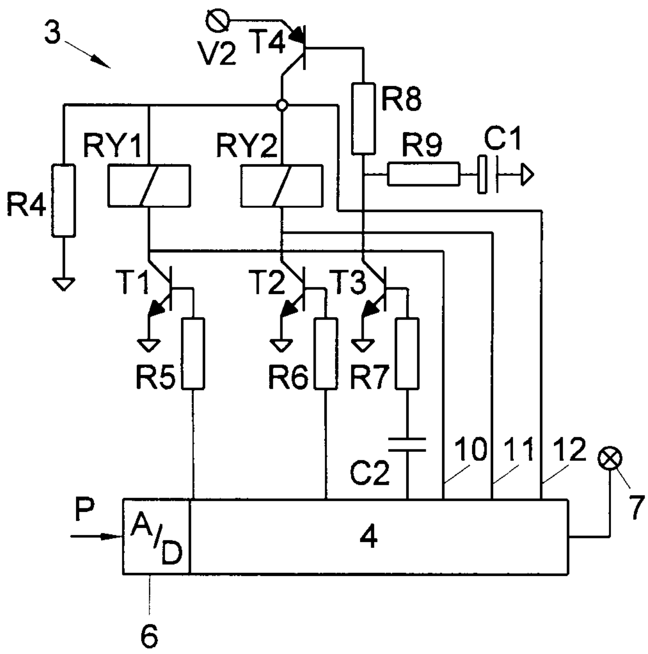

Fig. 2

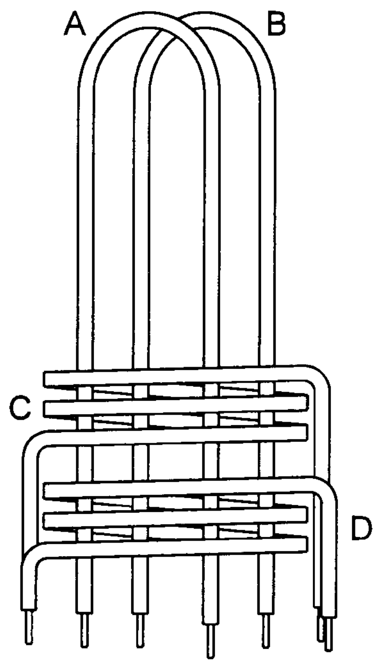

Fig. 3

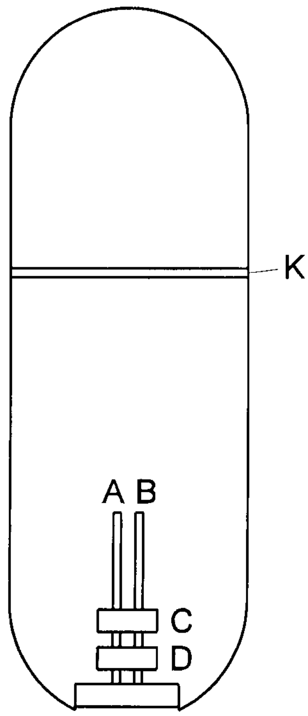

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 99 20 2932

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F24H
G01K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 October 1999	Ramboer, P

CATEGORY OF CITED DOCUMENTS

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