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(54) **DIAGNOSTIC METHOD FOR AN ELECTRIC HEATER**

(57) A diagnostic method for assessing the operational status of an heater, bases on the measurements of its electric insulation performances.

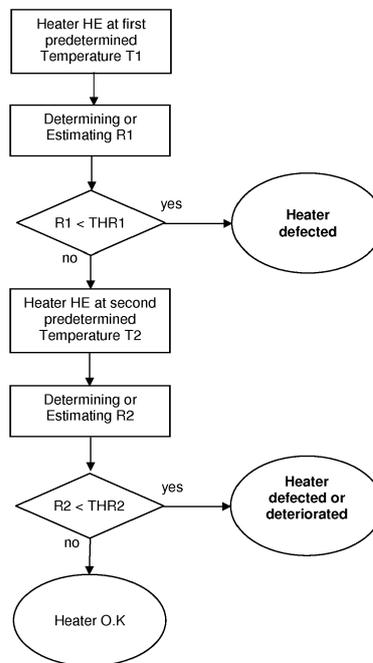


Fig. 4

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Description

[0001] The present invention relates to a diagnostic method for an electric heater which is part of a heating circuit of an appliance, preferably a domestic appliance, and an appliance configured to carry out such method.

[0002] More in detail, the object of the present invention is a method for determining when an electric heater installed into an appliance, preferably a domestic appliance, needs to be replaced because its operational status is deteriorated compared to its nominal working conditions/behavior.

[0003] It is generally known in the art that some appliances, particularly for household installation (i.e. domestic appliances such as a washing machine, a dishwasher, a boiler, a water kettle, an oven), are equipped with at least one electric heater. It is also generally known that thanks to aging and oxidation processes, such heaters deteriorates their performances during their lifetime. Such reduced performances include the lost of electrical insulation towards their supporting structure which causes electric current leakages from the component. In order to protect users from electric shocks, national and international standards request the connection to earth/ground of the supporting structure of the electric heater. At a certain level of performance, the electric heater needs to be replaced.

[0004] From EP-A-1266542 it is known a method according to which the temperature of the heater can be established through the measurement of leakage current. However the detection of failures of the heater based on leakage current are not therein considered, nor suggested.

[0005] From EP-A-0924331 it is known a safety circuit for monitoring the electric potentials of a circuit for washing machine or a dishwasher, which includes a heater. Potentials are monitored in order to verify whether the switches through which the heater is supplied, are properly configured. However, the disclosure of this application does not enable the specific diagnostic of the performances of the heating element.

[0006] Aim of the present invention is to further improve the methods known in the art which allows identifying a decreased performance or a fault of the electric heater and/or a missing or deteriorated electric connection of its support structure to earth/ground. These results are achieved through the steps as detailed in appended claim 1, alone, or in combination with the steps listed in the dependent claims.

[0007] Further features and advantages of the method according to the present invention will become apparent from the following non description of a preferred embodiment, meant as a not limiting example of the present invention, described in combination with the appended drawings, in which:

- Fig. 1 is a schematic diagram of a heating circuit according prior art;

- Fig. 2 is a second schematic diagram of a heating circuit according to prior art;
- Fig. 3 is a third schematic diagram of a heating circuit in which a resistive path towards earth/ground can be created through the water;
- Fig. 4 is a flow chart diagram describing the method according to the present invention.
- Fig. 5 is a flow chart diagram describing an alternative embodiment of the method according to the present invention.

[0008] It is here pointed out that consistent numbering references in the above mentioned drawings are used when describing the present invention.

[0009] In Fig. 1 it is described an example of heating circuit for an appliance known in the art, for instance a washing machine or a dishwasher through which the method of the present invention can be carried out. The heating circuit which is connected to the line L and neutral N terminals of the power supply network PS and comprises a series connection of a heating switching contact HRL and a heating element HE. The heating circuit optionally comprises a second switch HRN and/or safety switch.

[0010] As shown in Fig. 3 a household power plant, the neutral terminal L of the power supply network can be connected to ground/earth GND after the connection of the appliance to the same network with a plug G. A breaker B is also typically present in the household power plant.

[0011] In another embodiment (fig. 2) the heating circuit comprises a measuring resistor R_m branching-off at the junction a between the heating switching contact SW and the heating resistor HE. Possibly, the measuring resistor R_m is connected to the inoperative side of the safety switch SiS in which the heating circuit presents a specific potential of the supply voltage at that junction in the initial state (that is, when SW is open and the safety switch SiS is in its initial position).

[0012] In a preferred embodiment the heating element HE is a resistive heater, for instance a radiant tubular heater, even though the method of the present invention can be applied to any electric heater HE provided with an electric insulation.

[0013] In a preferred configuration of the appliance, the support of the heating element HE in said appliance is electrically connected to earth/ground GND, through an electric conductive path, together with the metallic chassis of said appliance.

[0014] Preferably, the heating element HE can enter in contact with water or, even more, being submerged by the water as it may occur in washing machines or in electric kettles, and through the water become connected to ground.

[0015] The electric conductive path to earth/ground GND potential can be also temporary, due to the presence of water inside the appliance, or created through a water stream flowing into or out from said appliance.

Flowing water and/or drained water can be generated through automatic actuation of a hydraulic valve and/or through the actuation of a pump.

[0016] The connection of the heating element to the power supply network L1, N1 may be effected in known manner via a logic circuit LC which controls the switch SW, which determines the actuation of the heating element HE, in a known manner.

[0017] The heating circuit further comprises a measuring circuit LS (a monitoring circuit) for measuring the electric parameters of the heating element HE. This measuring circuit LS can be integrated with the logic circuit LC into a single electronic control unit (an ECU)

[0018] Moreover, the measuring circuit could present at least one voltage divider and/or a filter for properly conditioning the monitored signal(s) to be sampled.

[0019] One or more voltage dividers SP1, SP2, SP3 connected on one side to junctions a, b and c and to the other side to the measuring circuit LS, can be implemented through impedance partitions, for instance through resistors R3 and R4, as illustrated in the embodiment of Fig.1. A filter can be implemented introducing additional capacitors and/or inductors in the monitoring circuit (not illustrated), or in a digital manner after the sampling process.

[0020] Voltage dividers can be connected at one or more terminals of the heating switching contact HRL, HRN and optionally to the safety switch SiS.

[0021] When required, sampled signals are acquired and processed by the measuring circuit LS. For instance they are compared with prescribed conditions stored into monitoring circuit (and/or into the control unit).

[0022] Depending on the status of the switches in the heating circuit and from the status of the heating element HE, voltages u_1 , u_2 and u_3 at the junctions change in the heating circuit, particularly at junction of the heating element HE.

[0023] As known in the art, prescribed potential conditions can be stored in the control unit, and they correspond to potential conditions which are correlated to the correct switching states of the heating circuit (e.g. initial position and operative state).

[0024] For the purposes of the present invention, the monitoring circuit LS is configured to determine (through a measurement) or to estimate any voltage linked with the heating element HE and/or any current flowing through the heating element H, including any leakage current of the same heater HE dispersed towards earth/ground GND, and/or the corresponding resistance to earth/ground GND of the same heating element HE.

[0025] For these purposes the heating circuit can include, in addition or in an alternative to the above described heating circuits, at least one shunt resistor (not illustrated) connected in series to the heating element in order to measure the current flowing through the heating element HE. In a more expensive alternative manner, a contactless Hall effect sensor (not illustrated) connected to the measuring circuit can be used to measure the elec-

tric current flowing through the heating element HE.

[0026] According to prior art, the safety of the heating circuit is obtained without temperature limiters or thermostats being used. In fact, if a fault occurs in the heating circuit, e.g. a short circuit, a component disconnection, a defective heating a switching contact and/or a defective safety switching contact, then the monitoring circuit detects a deviation from the permissible potential conditions and issues a switch-off signal, which may be used to switch-off the heating circuit or the machine. However, the same monitoring circuit can be used for measuring leakage currents and/or the resistance to ground/earth of the heating element HE through the measurements of voltages at least at one of its terminals.

[0027] According to the present invention the monitoring of these potentials will allow to determine not even when faults in the components of the heating circuit are present (as known in the art), but more specifically it will allow to establish whether the operating conditions of the heating element are sufficiently deteriorated for requiring the component to be replaced, even before to become completely inoperative (faulty). Moreover the monitoring of these potentials will further allow determining whether the electric connection to earth/ground of the heating element HE is deteriorated or even missing.

[0028] It is here pointed out that even though the present invention is described with reference to the resistance to earth/ground GND of the heating element HE, the measurement or the estimation of the leakage current of the heating element HE has to be understood as an equivalent measurement or estimation of said resistance to earth/ground GND of the same heating element HE, for the purposes of the present invention.

[0029] According to the method of the present invention in a first step the heating element HE is kept substantially stable at a first predetermined temperature T1. Preferably, this first predetermined temperature T1 is the ambient temperature, the temperature at which the heating element rests before to be operated. However, the step of keeping said electric heater at a first predetermined temperature T1 can also be achieved by operating the heating element in a known manner in order to bring it to a first stable controlled condition, i.e. a condition in which its average temperature is substantially stable at said first predetermined temperature T1 value.

[0030] In a second step a first resistance R1 to ground/earth of said heater HE is determined or estimated in a known manner through the measuring circuit LS, for instance as described in EP-A- 2353485 in regard to Rg.

[0031] It is here clarified that in any of the steps of determining or estimating the resistance to earth/ground R1 and/or R2 of the heating element HE which is linked to the value of its insulation resistance, include the step of sampling one or more voltage/current signals from said heating element HE and the step of processing said one or more voltage/current sampled signals.

[0032] During said steps the heating element HE can

be electrically supplied by closing one or more switch contacts (HRL, HRN, SiS) by the logic circuit LC and/or of a control circuit, before determining or estimating said resistance R1 and/or R2 to earth/ground GND.

[0033] In another embodiment (figure 3) an electric leakage current from said heating element flows over the water resistive path WP when determining or estimating said first resistance R1 ($=R_g+R_b$ in case of the water creates a resistive path through the support, or $=R_b$ in the case the resistive path is created directly through the water and the resistive element) to earth/ground GND and/or when determining or estimating said second resistance R2 to earth/ground GND.

[0034] According to the present invention, in a following third step, the first resistance to earth/ground R1 is compared with a first predetermined resistance threshold THR1 in order to establish if that heating element HE is deteriorated and/or if it has to be replaced.

[0035] More in detail, the resistance to ground of the heating element HE is compared with a range of expected values in order to establish the status of its insulating properties. The first predetermined resistance threshold THR1 is therefore in a range of values for which the insulating resistance of the electric or electronic component (HE) can be considered out of its operational specification, said insulating resistance being preferably in the range from 1 Ohm to 10 GOhm, optimally in the range from around 30 kOhm, up to more than 10 MOhm, and more preferably around 70 kOhm.

[0036] The value of said first predetermined resistance threshold THR1 determines the acceptable operating conditions at said first predetermined temperature T1 below which the heater should be replaced, and depends on the technology of which the heater is made.

[0037] Certainly, if the value of the resistance to ground R1 is lower than 300 kOhm, it could be assessed that the heating element HE is in defect, for instance it is in short circuit.

[0038] In a further fourth step, which can be alternative to said third step, said heating element HE is kept substantially stable to a second predetermined temperature T2, normally obtained by electrically operating the heating element, for instance by varying its duty cycle in a known manner. Preferably, the second predetermined temperature value T2 of said heating element HE is substantially different from said first predetermined temperature value T1 of said heating element HE in order to vary the insulating properties of the heating element HE, so that a significant variation of the resistance to earth/ground is expected for the heating element HE. Preferably the difference between the second predetermined temperature T2 and the first predetermined temperature is greater than 100 °C.

[0039] In a further fifth step following the third step, a second resistance R2 to earth/ground GND of said heater HE is determined or estimated in a known manner through the measuring circuit LS.

[0040] In a further sixth step, said second resistance

R2 to earth/ground is compared to a second predetermined threshold value THR2, in order to establish whether the operating conditions of the heating element HE are deteriorated and/or if the heating element HE has to be replaced.

[0041] More in detail, the resistance to ground of the heating element HE, which is linked to the changes of its insulation properties (the resistivity), varies with the temperature of the heating element HE. For a heating element HE in acceptable operating conditions (i.e. not presenting deteriorations) the second resistance to earth/ground R2 measured at higher temperature is expected to be lower than the first resistance to earth/ground R1 of the same heater HE measured at lower temperature. As a consequence, according to the present invention the second predetermined resistance threshold THR2 should be lower than said first predetermined resistance threshold THR1 and is optimally in the range between 100 kOhm and 1M Ohm, preferably about 300 kOhm.

[0042] The value of said second predetermined resistance threshold THR2 determines the acceptable operating conditions at said second predetermined temperature T2 below which the heater should be replaced, and depends on the technology of which the heater is made.

[0043] In a step alternative to the above sixth step, the second resistance R2 to ground/earth is directly compared with said first resistance R1 to ground/earth, in order to establish whether the operating conditions of the heating element HE are deteriorated and/or if the heating element HE has to be replaced.

[0044] A more accurate control can be made by taking into consideration the tolerances of the power supply voltage, as described in EP-A- 2353485.

[0045] Finally, according to the present invention the appliance can be further provided with a user interface for notifying the user in case of a fault of the heating circuit, or in case of decreased performances of said heating circuit, in particular of said heating element HE.

[0046] It has been so disclosed here a diagnostic method for an electric heater which is part of a heating circuit of an appliance. According to the method, the reliability of the heating circuit is further improved by evaluating the operating conditions of the heating element HE.

[0047] It is also disclosed here an appliance, preferably a domestic appliance specifically configured for carrying out the method above described.

Claims

1. Diagnostic method for an electric heating element (HE) of an appliance, preferably a domestic appliance, provided with a logic unit (LC) for monitoring said heating circuit, the heating element (HE) being provided with a support connected to earth/ground (GND) for dispersing leakage currents, the method comprising the step of:

- keeping the heating element (HE) substantially stable at a first predetermined average temperature value (T1);
 - determining or estimating a first resistance (R1) of said heating element (HE) to ground/earth (GND) at said first predetermined temperature value (T1),
 - **characterised in that** the method further comprises a step of comparing said determined or estimated first resistance (R1) to earth/ground (GND) with a first predetermined resistance threshold (THR1) in order to assess a decreased performance or a fault in said heating element (HE).
2. Method according to claim 1 further comprising the steps of
- keeping the heating element (HE) substantially stable at a second predetermined average temperature value (T2), this step being additional or alternative to the step of comparing said determined or estimated first resistance (R1) to earth/ground (GND) with a first predetermined resistance threshold (THR1),
 - determining or estimating a second resistance (R2) to earth/ground (GND) of said heating element (HE) at said second predetermined temperature value (T2),
 - and also comprising the step of comparing said second resistance (R2) to ground/earth to a second predetermined resistance threshold (THR2) in order to further in order to assess a defect or a fault in said heating element (HE).
3. Method according to claim 1 further comprising the steps of
- keeping the heating element (HE) substantially stable at a second predetermined average temperature value (T2), this step being alternative to the step of comparing said determined or estimated first resistance (R1) to earth/ground (GND) with a first predetermined resistance threshold (THR1),
 - determining or estimating a second resistance (R2) to earth/ground (GND) of said heating element (HE) at said second predetermined temperature value (T2),
 - and also comprising the step of comparing said first resistance (R1) to earth/ground (GND) to said second resistance (R2) to earth/ground (GND), in order to further assess whether there is a missing or deteriorated electrical connection to earth/ground (GND) of the heating circuit and/or of said appliance containing said heating circuit.
4. Method according to claim 1 or 2 wherein the step of keeping the heating element (HE) substantially stable at said first predetermined average temperature value (T1) or to said second predetermined average temperature value (T2) is achieved by electrically operating the heating element (HE) in a controlled manner by a logic circuit (LC).
5. Method according to any of the preceding claims in which the step of determining or estimating said first resistance (R1) to earth/ground (GND) or said second resistance (R2) to earth/ground (GND) of said heating element (HE), further include the step of sampling one or more voltage/current signals from said heating element (HE) and the step of processing said one or more voltage/current sampled signals in order to determine or to estimate an insulation resistance of said electric or electronic component (HE).
6. Method according to any of the preceding claims in which said heating element (HE) is electrically supplied by closing one or more switch contacts (HRL, HRN, SiS) by a logic circuit (LC) and/or of a control circuit before determining or estimating at least one of said first resistance (R1) to earth/ground (GND) or said second resistance (R2) to earth/ground (GND), of said heating element (HE).
7. Method according to any of the preceding claims in which said first predetermined resistance threshold (THR1) is in a range of values for which the insulating resistance of the electric or electronic component (HE) can be considered out of it operational specification, said insulating resistance being preferably in the range from 1 Ohm to 10 GOhm, optimally in the range from around 30 kOhm, up to more than 10 MOhm, and more preferably around 70 kOhm.
8. Method according to any of the preceding claims in which said second predetermined resistance threshold THR2 is lower than said first predetermined resistance threshold THR1 and is optimally in the range between 100 kOhm and 1M Ohm, preferably about 300 kOhm.
9. Method according to any of the preceding claims wherein said first predetermined temperature value (T1) of said heating element (HE) is substantially different from said second predetermined temperature value (T2) of said heating element (HE).
10. Method according to any of the preceding claims wherein a temporary resistive path is created by flowing a water stream into said appliance or by draining water from said appliance, preferably through automatic actuation of a hydraulic valve and/or through the actuation of a pump, and through which electric

leakage current flows when determining or estimating said first resistance (R1) to earth/ground (GND) and/or said second resistance (R2) to earth/ground (GND).

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11. Method according to any of the preceding claims wherein, when a failure or decreased performances are detected, the appliance notifies it to a user with a visual and/or with an acoustic signal.

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12. Appliance, preferably a domestic appliance, provided with at least a heating circuit which comprises a heating element (HE), the appliance being also provided with a monitoring circuit and/or a logic circuit (LC) for the detection of a fault of said heating element (HE) **characterized in that** the appliance is configured to implement a method according to any of the preceding claims.

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13. Appliance according to claim 13 in which said appliance is configured for having the heating element (HE) in an electric conductive path to earth/ground (GND) due to the presence of water in the appliance.

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14. Appliance according to claim 13 or 14 further provided with a user interface for notifying the user in case of a fault or in case of decreased performances of said heating circuit, in particular of said heating element (HE).

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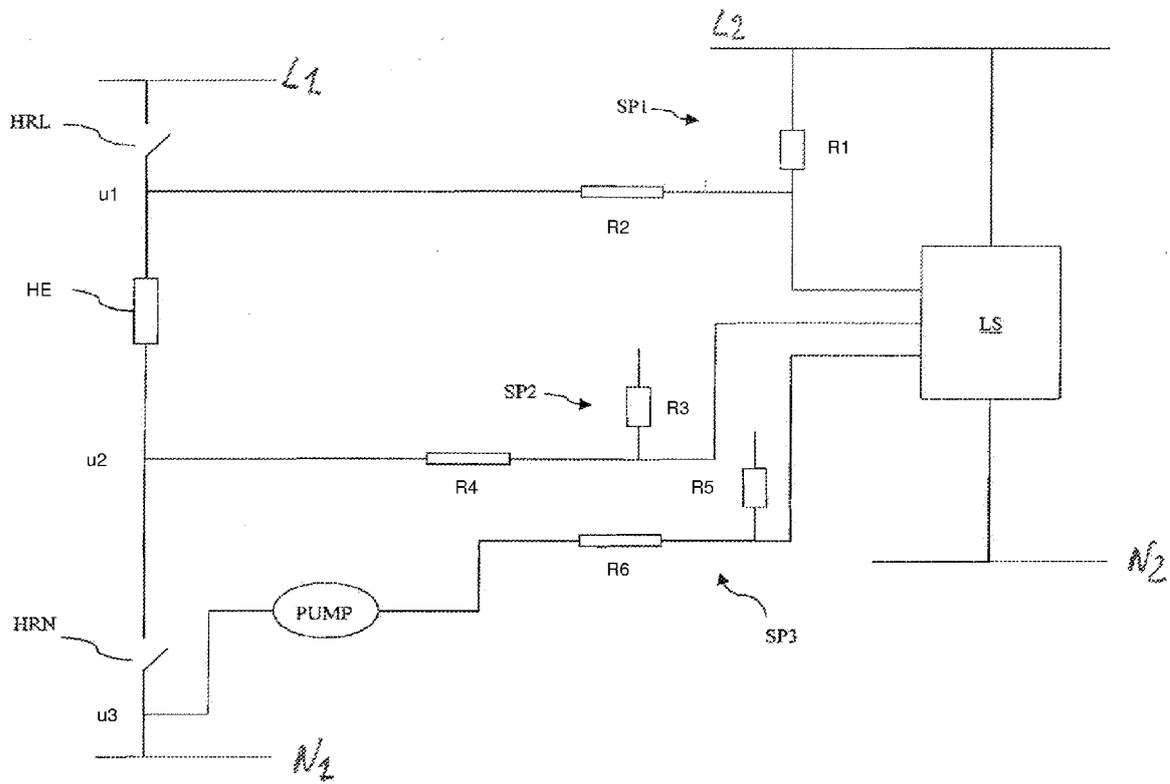


Fig. 1 (prior Art)

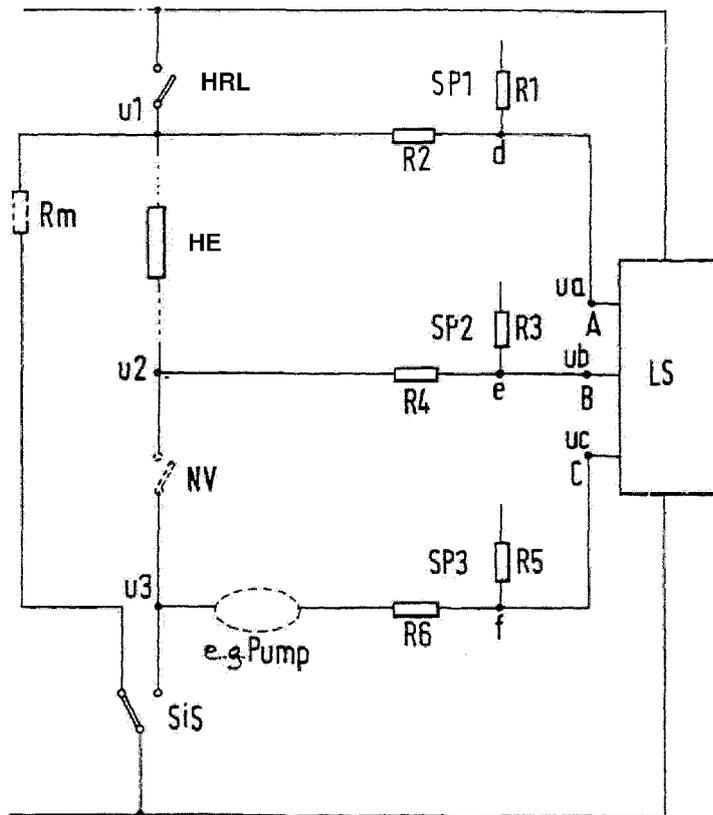


Fig. 2 (prior art)

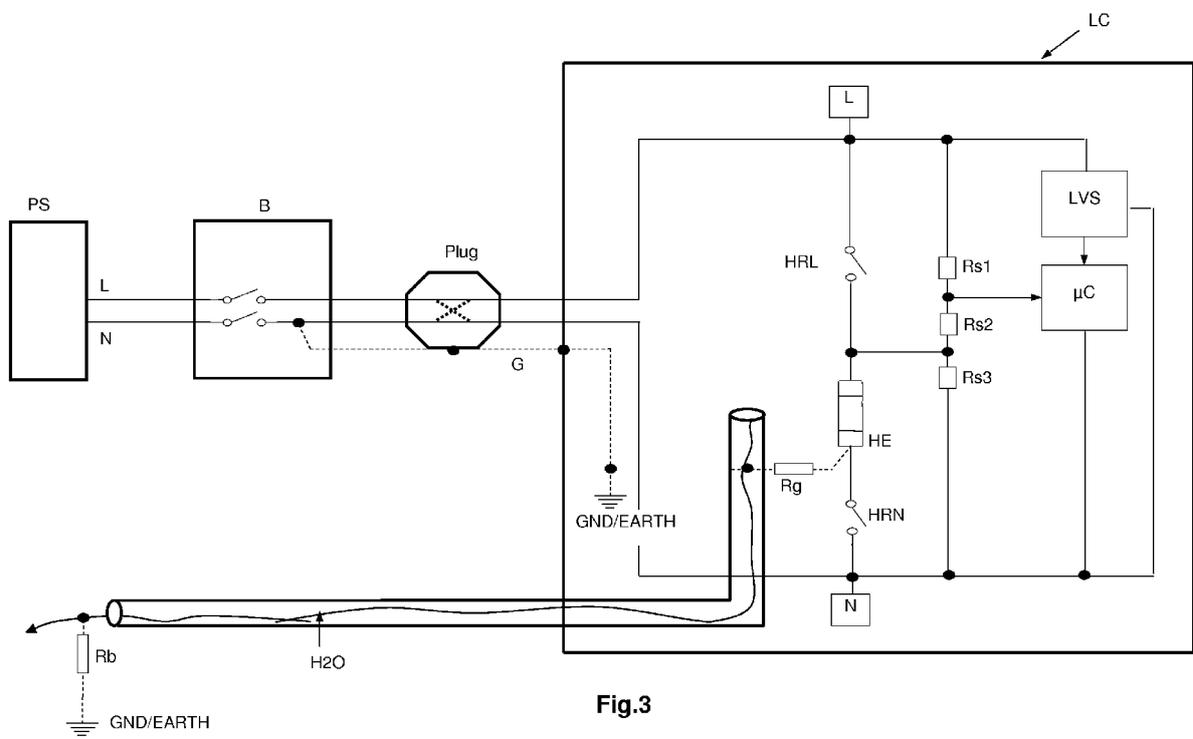


Fig.3

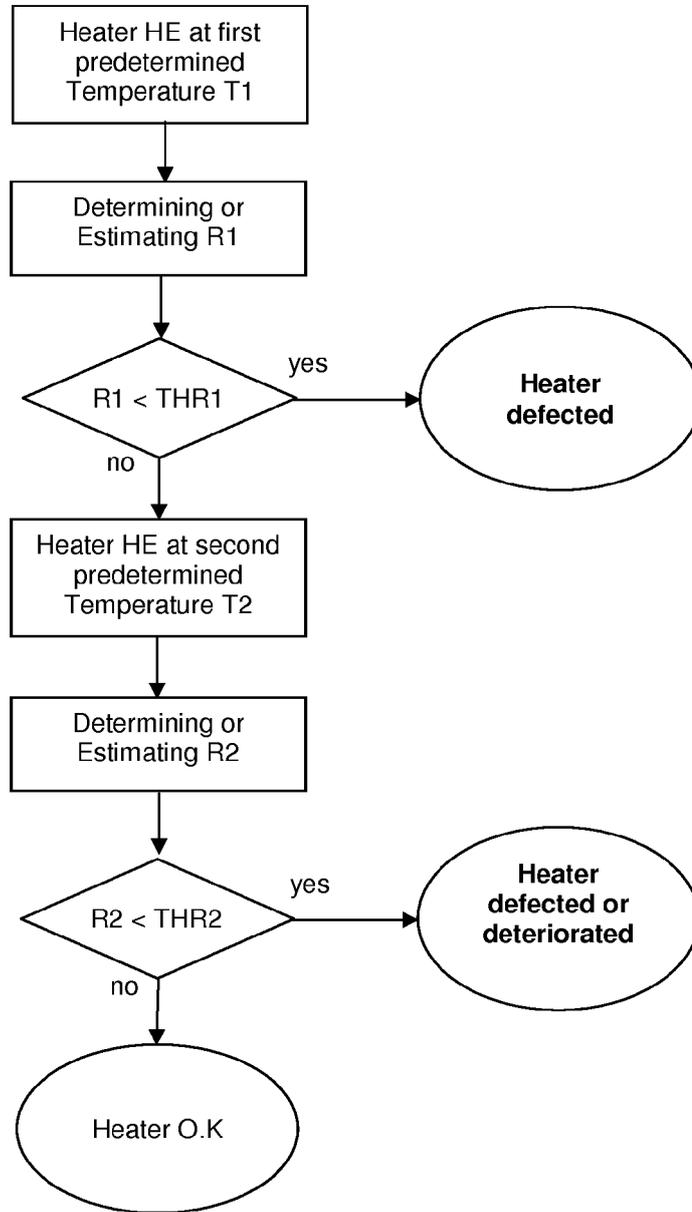


Fig. 4

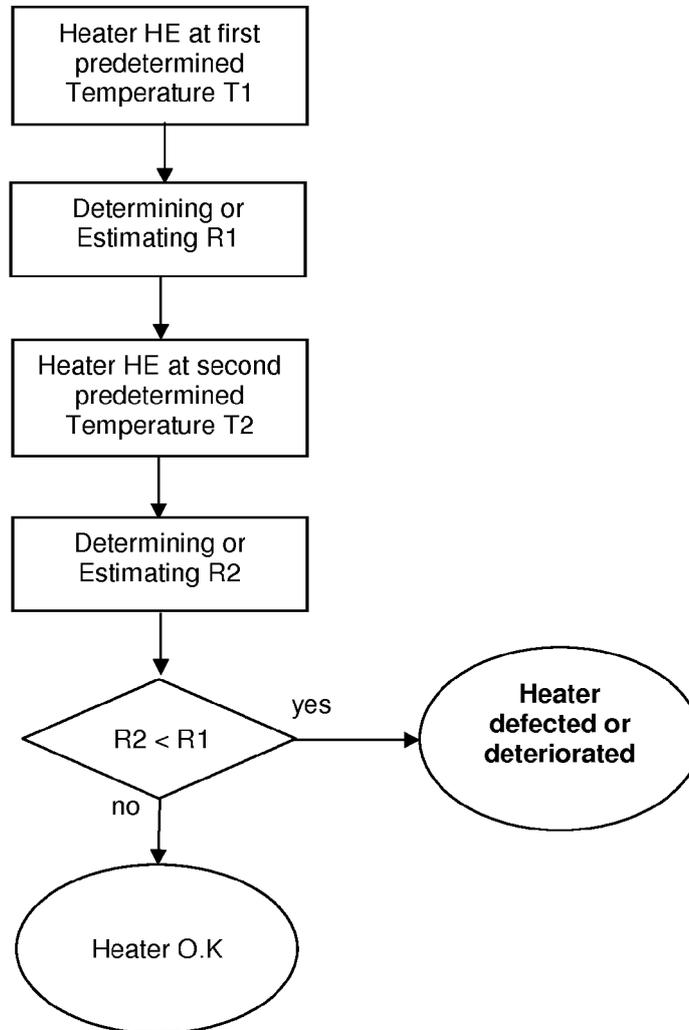


Fig. 5



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Place of search Munich		Date of completion of the search 4 May 2016	Examiner Gea Haupt, Martin
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