

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
10 July 2003 (10.07.2003)

PCT

(10) International Publication Number  
WO 03/055544 A1

(51) International Patent Classification<sup>7</sup>: A61M 1/16,  
G01K 13/02, 1/14

(21) International Application Number: PCT/IB02/05572

(22) International Filing Date:  
20 December 2002 (20.12.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
MI01A002828 28 December 2001 (28.12.2001) IT

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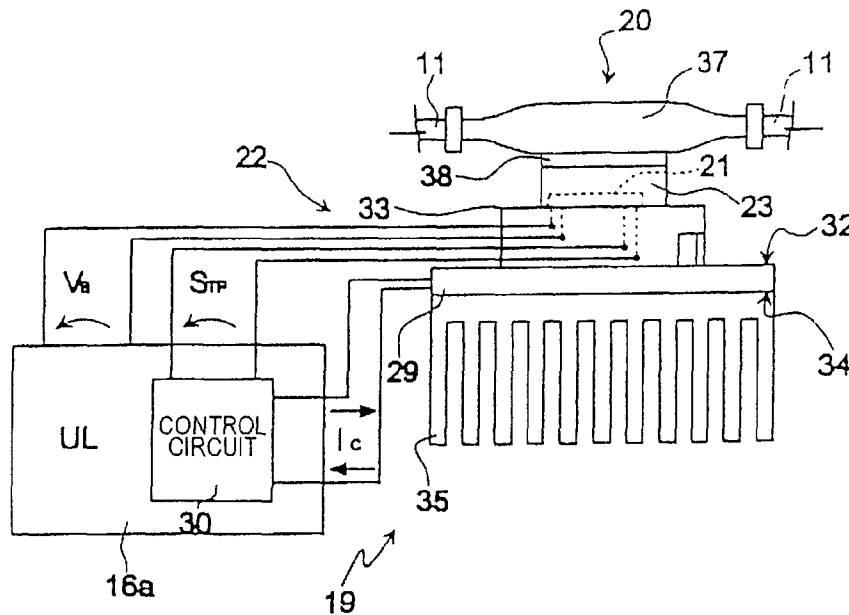
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(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

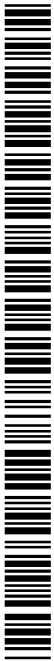
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SI, SK,

[Continued on next page]

(54) Title: NON-INVASIVE DEVICE FOR MEASURING BLOOD TEMPERATURE IN A CIRCUIT FOR THE EXTRACORPOREAL CIRCULATION OF BLOOD, AND EQUIPMENT PROVIDED WITH THIS DEVICE



(57) Abstract: A non-invasive device (16) for measuring blood temperature in a circuit for the extracorporeal circulation of blood includes a line (20) in which blood taken from a patient flows (P), and a temperature sensor (19), connected to the said line (20) and provided with a device (21) for measuring the intensity of an electromagnetic radiation. The measuring device (21) faces a connecting portion or window (37) of the line (20) which is permeable by electromagnetic radiation in a first wave band (B<sub>S</sub>), and generates a first signal (V<sub>B</sub>), correlated with the electromagnetic radiation in the first band (B<sub>S</sub>) and therefore, with the temperature of the blood flowing in the line (20).



WO 03/055544 A1



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TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**Published:**

— *with international search report*

NON-INVASIVE DEVICE FOR MEASURING BLOOD TEMPERATURE IN A  
CIRCUIT FOR THE EXTRACORPOREAL CIRCULATION OF BLOOD, AND  
EQUIPMENT PROVIDED WITH THIS DEVICE

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DESCRIPTION

The present invention relates to a non-invasive device for measuring blood temperature in a circuit for the extracorporeal circulation of blood, and to equipment provided with this device.

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It is known that one of the problems closely associated with the use of circuits for the extracorporeal circulation of blood is that of monitoring the blood temperature. This is because the human body maintains the blood temperature at an essentially constant level of approximately 37°C, with very limited variations contained within a few tenths of a degree Celsius (in non-pathological conditions). Larger variations can result in an imbalance in the body, causing damage which may be severe. However, during its extracorporeal circulation, the blood gives up some of its heat to the surrounding environment, and this may result in excessive and prolonged lowering of the blood temperature, such that metabolic imbalance is caused, especially in vulnerable patients.

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Special arrangements must therefore be made for certain types of machines, such as dialysis machines, which use a circuit for extracorporeal circulation. Dialysis treatments have to be repeated frequently and for prolonged periods, and it is therefore particularly important to protect the patient from the risks described above. Moreover, a dialysis machine uses a filter having a first compartment, in which the blood flows, and a second compartment, in which there flows a dialysate which may be at a temperature different from the blood temperature. The two compartments are separated from each other by a semi-permeable membrane which allows heat to be transferred from the blood to the dialysate and vice versa. For this reason also, the problem of monitoring the blood temperature is very important in the field of dialysis machines. Similar problems arise when haemofiltration and haemodiafiltration treatments are carried out.

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Various methods have been proposed for monitoring the blood temperature during extracorporeal circulation, the efficacy of these methods being dependent on the possibility of measuring in a precise and rapid way the patient's blood temperature

immediately downstream of the collection point and upstream of the return point. This temperature is measured indirectly by means of a non-invasive measurement system comprising a temperature sensor connected to a portion of the extracorporeal circuit. In greater detail, in known measurement systems a portion of a line of the extracorporeal circuit is housed in an aluminium element shaped in such a way that it has a large heat exchange surface in contact with the said line. A platinum thermistor is placed in contact with the aluminium element and is used to measure the temperature of the latter. In conditions of thermal equilibrium, the temperature of the line and therefore of the blood flowing in it is related to the temperature of the aluminium element by a known relation and can be determined from the signal supplied by the thermistor. In order to reduce the effect of the external environment on the result of the measurement, the transducer formed in this way (the aluminium element and the thermistor) is inserted into a support, also made from aluminium, which is kept at the same temperature as the line by a heater controlled by a suitable control unit. Thus the heat exchange between the transducer and the external environment is minimized, and the measured temperature depends solely on the heat exchange with the line. The space between the transducer and the heated support is filled with a material (for example, PVC) chosen in such a way as to optimize the compromise between the speed of response of the sensor and the thermal insulation from the external environment.

However, the known systems have a number of drawbacks. This is because the lines forming the extracorporeal circuit are normally made from material with low thermal conductivity, in order to prevent a damaging loss of heat. The thermal coupling between the blood flowing within the extracorporeal circuit and the aluminium element is therefore poor, and the measurement made in the way that has been described is inevitably of low accuracy. In particular, the known systems have very long response transients, since a variation in blood temperature is detected only after a new state of thermal equilibrium has been established among the blood flow, the wall of the extracorporeal circuit, the transducer and the heated support.

The object of the present invention is to provide a non-invasive device for measuring the blood temperature in a circuit for the extracorporeal circulation of blood, which is free of the drawbacks of the known art.

According to the present invention, a non-invasive device is provided for measuring blood temperature in a circuit for the extracorporeal circulation of blood, this

device comprising a line in which blood taken from a patient flows, and a temperature sensor, connected to the said line and generating a first signal correlated with the temperature of the blood flowing in the said line, characterized in that the said temperature sensor comprises a device for measuring the intensity of an electromagnetic radiation, and the said line comprises a connecting portion facing the said measuring device and permeable by electromagnetic radiation in a first wave band; the said first signal being correlated with the intensity of the said electromagnetic radiation in the said first band.

The device according to the invention advantageously permits the measurement of a quantity directly correlated with the patient's blood temperature, namely the electromagnetic radiation emitted by the blood at a certain temperature in a predetermined frequency band. Secondly, the portion of the extracorporeal circuit on which the measurement is made is connected to the sensor in such a way that the fraction of electromagnetic radiation emitted by the blood and incident on the measuring device is maximized. Furthermore, the devices for measuring electromagnetic radiation, comprising a thermopile in a preferred embodiment of the invention, have very short response transients. The device therefore has very high precision, accuracy and speed of response. In practice, the blood temperature can be measured with an error of less than 0.1°C and with transients of the order of hundredths of a second.

The present invention also relates to control equipment in an extracorporeal blood circuit, as specified in Claim 20.

To enable the present invention to be more clearly understood, a preferred embodiment thereof will now be described, purely by way of example and without restrictive intent, with reference to the attached figures, of which:

- Figure 1 is a schematic view, with parts removed for clarity, of a dialysis machine equipped with a blood temperature measuring device constructed according to the present invention;
- Figure 2 is a schematic view in side elevation of the measuring device of Figure 1;
- Figure 3 is an exploded view of the device of Figure 1, with parts removed for clarity;
- Figure 4 is a perspective view of a detail of the device of Figure 3;

- Figure 5 is a graph showing characteristics of parts of the device of Figure 2;
- Figure 6 is a partial schematic view of the detail of Figure 4; and
- Figure 7 is a schematic view, with parts removed for clarity, of a dialysis machine equipped with a blood temperature measuring device constructed according to a variant of the present invention.

In the example of embodiment described below, the invention is used for monitoring the blood temperature during a dialysis treatment.

In Figure 1, the number 1 indicates the whole of a dialysis machine connected to a patient P. The machine 1 comprises an extracorporeal blood circuit 2, a filter 3 including a blood compartment 5 and a dialysate compartment 6 separated by a semi-permeable membrane 7, a dialysate circuit 8 connected to the dialysate compartment 6, an infusion circuit 9 and equipment 10 for regulating the blood temperature.

The extracorporeal blood circuit 2 comprises an arterial branch 11, in which a peristaltic pump 12 is located, and a venous branch 13. The arterial branch 11 has one end connected to the blood compartment 5 and one end connected to a fistula (not illustrated) in the patient P to collect the blood from the cardiovascular system of the patient P, while the venous branch 13 has one end connected to the blood compartment 5 and an opposite end fitted into the aforesaid fistula (not illustrated) to return the treated blood to the cardiovascular system of the patient P. The branches 11 and 13 are tubes made from plastic material, used, respectively, for supplying the blood to be treated to the compartment 5 and for introducing into the cardiovascular system the treated blood leaving the compartment 5.

The infusion circuit 9 is connected to a pre-dilution node 15a, located in the arterial branch 11, and to a post-dilution node 15b, located in the venous branch 13, and supplies a controlled quantity of an infusion solution to the extracorporeal circuit 2, in a known way. Alternatively, the infusion circuit 9 is connected only to the pre-dilution node 15a or only to the post-dilution node 15b.

The equipment 10 for regulating the blood temperature comprises a non-invasive device 16 for measuring the blood temperature, located in the arterial branch 11 and provided with a control unit 16a, a state sensor 17 for detecting whether the peristaltic pump 12 is in operation, and a temperature regulating device 18, located in a portion 13a of the venous branch 13 of the extracorporeal circuit 2 downstream of the post-dilution node 15b, in such a way that it combines with the portion 13a to form a

heat exchanger. The regulating device 18 is also connected to an output of the device 16 supplying a blood temperature signal  $S_{TB}$ .

The device 18 regulates the blood temperature in the portion 13a without adding mass to the blood flow. In other words, the regulating device 18 acts on a fluid which is separated physically from the blood and whose temperature  $T_F$  is monitored by the unit 16a in a range from  $20^{\circ}\text{C}$  to  $43^{\circ}\text{C}$  in such a way as to supply heat to, or remove it from, the blood flowing in the venous branch 13 directly before the blood is returned to the patient P.

The regulating device 18 comprises at least one line 18a, which forms a set of windings or a nest of tubes and provides a seat 18b for housing the portion 13a of the venous branch 13, and a heater/cooler 18c connected to the control unit 16a.

During operation, in the course of the dialysis treatment the blood is collected from the patient P and is conveyed along the extracorporeal circuit 2. The non-invasive device 16 measures the temperature  $T_P$  and the control unit 16a controls the regulating device 18, on the basis of a predetermined algorithm, as a function of the temperature  $T_P$  and a reference temperature  $T_{SET}$  which is set by an operator at the control unit 16a.

For example, the control unit 16a compares the temperature  $T_P$  with the reference temperature  $T_{SET}$ , which is generally  $37^{\circ}\text{C}$ , and calculates the temperature difference  $\Delta T$  between the temperature  $T_P$  and the reference temperature  $T_{SET}$ . At the start of the dialysis treatment, the regulating device 18 keeps the temperature  $T_F$  of the fluid at a value equal to the reference temperature  $T_{SET}$ , while the temperature  $T_D$  of the dialysate is regulated in such a way as to optimize the haemodialysis treatment. During the haemodialysis treatment, the blood temperature  $T$  in the extracorporeal circuit 2 varies as a result of the heat exchange with the surrounding environment, with the dialysate, and with the fluid conveyed within the regulating device 18, and as a function of the reaction of the patient P to the materials used in the treatment of the blood.

The temperature  $T_P$  is measured by the non-invasive device 16, for example, at relatively short time intervals during the dialysis treatment, and the control unit 16a calculates the temperature difference  $\Delta T$  at the same frequency as that of the measurement of the temperature  $T_P$ . When the temperature difference  $\Delta T$  between the temperature  $T_P$  and the reference temperature  $T_{SET}$  takes a negative value, the fluid temperature  $T_F$  is increased in such a way as to supply heat to the blood in the portion 13a, while when the temperature difference  $\Delta T$  takes a positive value the fluid

temperature  $T_F$  is reduced in such a way as to remove heat from the blood in the portion 13a. The repetition of the procedure described above at short time intervals makes it possible to rapidly stabilize the temperature  $T_P$ , in other words the temperature of the patient P, at a value close to the reference temperature  $T_{SET}$ , whenever the temperature 5  $T_P$  varies with respect to the reference temperature  $T_{SET}$ .

The sensor 17 detects the state of operation of the pump 12 and emits a signal to indicate when the pump 12 is operational and when it is stopped. If the signal emitted by the sensor 17 indicates that the pump 12 is in a stopped state, the control unit 16a keeps the value of  $T_F$  equal to the reference temperature  $T_{SET}$ ; if, on the other hand, the 10 signal indicates that the pump 12 is in an operational state, the fluid temperature  $T_F$  is regulated as a function of the temperature difference  $\Delta T$  according to the procedure described above.

In a variant of the operation, the reference temperature  $T_{SET}$  is not fixed, but varies during the dialysis treatment according to a specified profile.

15 As illustrated in Figures 2 and 3, the device 16 comprises a temperature sensor 19, a line 20 fitted in the arterial branch 11 and connected to the sensor 19, and the digital and/or analogue control unit 16a.

In greater detail, the sensor 19 comprises a thermopile 21 and a temperature control device 22. The thermopile 21 is housed within a casing 23 (Figure 4), in a 20 window 24 formed in the said casing 23, and has a pair of measuring terminals 25 connected to the control unit 16a. Between these terminals 25 there is a voltage  $V_B$  correlated with the intensity of the electromagnetic radiation striking the thermopile 21 through the window 24 and having a predetermined measurable waveband  $B_S$ , at least partially included in the infrared band IR (Figure 5). The operating principle of a 25 thermopile is based on the Seebeck effect. In particular, the thermopile 21 preferably has a plurality of hot junctions 21a and cold junctions 21b connected together in series, as shown in Figure 6. The hot junctions 21a are located in an area of absorption 21c which absorbs the incident electromagnetic radiation and modifies its own temperature as a result. The cold junctions 21b are supported by a support 21d of semiconductor 30 material placed in contact with the casing 23 (Figure 4) in which the thermopile 21 is housed. The voltage  $V_B$  generated by the thermoelectric effect is a function of the temperature difference between the hot junctions 21a and the cold junctions 21b, in other words between the absorption area 21c and the support 21d. In order to have a

voltage  $V_B$  which is different from zero and dependent solely on the intensity of the electromagnetic radiation, and in order to have a high signal-to-noise ratio as well, the temperature of the support 21d, on which the cold junctions 21b are located, must be kept at a value sufficiently lower than the operating temperature range within which the thermopile 21 is to be used. For this purpose, use is made of the control device 22 which keeps the casing 23 and consequently the support 21d at a controlled and constant operating temperature, in the range from 5°C to 15°C and preferably at 10°C. With reference to Figures 2 - 4, the control device 22 comprises a thermistor 28 (Figure 4), a solid-state heat pump 29 and a control circuit 30, preferably integrated in the control unit 16a (Figure 2). The thermistor 28 is located within the casing 23 and is thermally connected to the cold junctions 21b of the thermopile 21 by means of the casing 23 and the support 21d; additionally, the thermistor 28 has a pair of terminals 31 connected to the control circuit 30 and supplying an electrical signal  $S_{TP}$ , correlated with the operating temperature of the thermopile 21. The heat pump 29 is a thermoelectric module, for example a Peltier cell, which causes heat to be transferred between its two opposite surfaces when an electrical current passes through it, and therefore has a cold surface 32 and a hot surface 34 (Figures 2 and 3). The cold surface 32 is connected to the casing 23 of the thermopile 21 by means of a heat-conducting support 33 (made from copper, for example), which is pierced so that it can house the thermopile 21. The hot surface 34 is connected to a heat sink 35 to promote the dispersion of the heat extracted by the said heat pump 29. The heat pump 29 also has a pair of terminals 36 connected to the control circuit 30, which, in a known way, supplies a control current  $I_c$  correlated with the electrical signal  $S_{TP}$ .

As shown in Figures 2 and 3, the line 20, in which the blood collected from the patient P flows, comprises a connecting portion 37, facing the thermopile 21 and permeable by the electromagnetic radiation in the measurable band  $B_S$ . In greater detail, the connecting portion 37 is of discoid shape and is completely superimposed on the window 24 of the casing 23 in which the thermopile 21 is housed, in such a way that it completely covers the solid angle of view of the thermopile 21. Additionally, the connecting portion 37 is made from a material having negligible absorbance and high transmittance in the measurable band  $B_S$  and in a temperature range from 30°C to 40°C. Preferably, this material is chosen from high-density polyethylene, low-density polyethylene and poly(4-methyl-1-pentene) (PMP). Thus the fraction of electromagnetic

radiation emitted by the blood of the patient P in the temperature range from 30°C to 40°C and striking the thermopile is maximized.

5 A filter 38, comprising a sheet of a material which is essentially opaque to electromagnetic radiation outside a pass band  $B_P$  lying within the measurable band  $B_S$  (Figure 5), is interposed between the thermopile 21 and the line 20 (Figures 2 and 3). In particular, the filter 38 is supported by the casing 23, and has a first face 39 positioned so that it covers the window 24, and a second face 40, opposite the first face 39 and facing the connecting portion 37 of the line 20. In the embodiment of the invention described herein, the filter 38 is made from suitably treated germanium, and the pass  
10 band  $B_P$  is in the range from 8  $\mu\text{m}$  to 14  $\mu\text{m}$  (infrared).

During the dialysis treatment, the blood collected from the cardiovascular system of the patient P flows through the line 20 and emits electromagnetic radiation in the measurable band  $B_S$ . A fraction of the electromagnetic radiation emitted through the filter 38 and the window 24 strikes the thermopile 21, thus contributing to the  
15 determination of the value of the voltage  $V_B$  between the terminals 25. In greater detail, the variations of the voltage  $V_B$  are due exclusively to the variations of intensity of the electromagnetic radiation which is emitted by the blood flowing in the connecting portion 37 and which strikes the thermopile 21. This is because, since the connecting portion 37 is positioned so that it entirely covers the solid angle of view of the  
20 thermopile 21 through the window 24, the flow of electromagnetic radiation through the window 24 is essentially due solely to the electromagnetic radiation emitted by the blood flowing in the connecting portion 37; additionally, the casing 23 of the thermopile 21 is kept at a constant known temperature by means of the device 22, and consequently makes a constant contribution to the voltage  $V_B$ .

25 The intensity of the radiation is also correlated with the temperature  $T_P$  of the body by which it is emitted, in other words the blood of the patient P. More specifically, the total power of the emitted infrared radiation is a function of the temperature of the radiating body, according to the Stefan-Boltzmann law. The intensity of the emitted radiation increases with an increase in the temperature of the radiating body. In the case  
30 in question, the filter 38 selects only the electromagnetic radiation lying within the pass band  $B_P$ , and the voltage  $V_B$  generated by the thermopile 21 depends on the energy absorbed in this pass band  $B_P$ .

The temperature  $T_p$  can therefore be determined on the basis of the value of the voltage  $V_B$ , according to a known relation of the following type:

$$T_p = F(V_B) + T_0 \quad (1)$$

where  $F(V_B)$  is an experimentally determined function and  $T_0$  is the operating temperature at which the casing 23, the support 21d and the cold junctions 21b of the thermopile 21 are all maintained.

In ordinary operating conditions, the variations of the temperature  $T_p$  are not more than a few degrees Celsius, and therefore the relation (1) can be approximated by the relation:

$$T_p = T_0 + K * V_B \quad (2)$$

where  $K$  is a known constant, since it is experimentally determined.

With reference to Figure 7, the number 45 indicates a haemofiltration machine comprising the extracorporeal circuit 2 and a haemofiltration filter 46 comprising a blood compartment 47 and a compartment 48 separated by a semi-permeable membrane 49. The machine 45 is equipped with the blood monitoring equipment 10 and, in particular, is provided with the non-invasive device 16.

The machine 45 can carry out pure haemofiltration treatments and haemofiltration treatments in pre- and/or post-dilution.

The equipment 10 applied to the machine 45 is completely identical to that associated with the machine 1, and its operation is also identical.

The equipment 10 is particularly advantageous in that it can be connected to any type of blood purification machine, and does not require adaptation to the type of purification treatment in use.

Finally, modifications and variations can clearly be applied to the device described without departure from the scope of the present invention. In the first place, the use of the invention is not limited to dialysis machines alone, but can be extended to all cases in which a circuit for extracorporeal blood circulation is used. It is also possible to use infrared radiation measuring devices other than those described, such as devices made from semiconductor material with PN junctions. The non-invasive device could also be provided with a dedicated control unit, separate from that which is used to control the other parts of the equipment for regulating the blood temperature. The heat pump used can also be different from a Peltier cell. As an alternative to the use of a heat

pump, it is possible to directly compensate the signal from the thermopile 21 by using the temperature of the casing 23, which can be measured by means of the thermistor 28.

CLAIMS

1. Non-invasive device for measuring blood temperature in a circuit for the extracorporeal circulation of blood, this device comprising a line (20) in which blood  
5 taken from a patient flows (P), and a temperature sensor (19), connected to the said line (20) and generating a first signal ( $V_B$ ) correlated with the temperature ( $T_P$ ) of the blood flowing in the said line, characterized in that the said temperature sensor (19) comprises a device (21) for measuring the intensity of an electromagnetic radiation, and the said line (20) comprises a connecting portion (37) facing the said measuring device (21) and  
10 permeable to electromagnetic radiation in a first wave band ( $B_S$ ); the said first signal ( $V_B$ ) being correlated with the intensity of the said electromagnetic radiation in the said first band ( $B_S$ ).
2. Device according to Claim 1, characterized in that the said measuring device (21) is housed within a casing (23), behind a window (24) formed in the said casing  
15 (23); the said connecting portion (37) of the said line (20) being completely superimposed on the said window (24), in such a way that it completely covers the solid angle of view of the said measuring device (21).
3. Device according to Claim 1 or 2, characterized in that the said measuring device (21) comprises a thermopile, having at least one hot junction (21a) and at least  
20 one cold junction (21b).
4. Device according to Claim 3, characterized in that the said temperature sensor (19) comprises means (22) of controlling the temperature, to keep the cold junction (21b) of the said measuring device (21) at a controlled temperature ( $T_0$ ).
5. Device according to Claim 4, characterized in that the said control means (22)  
25 comprise:
- a thermistor (28), connected thermally to the cold junction (21b) of the said measuring device (21), and supplying a second signal ( $S_{TP}$ ), correlated with the said controlled temperature ( $T_0$ );
  - a solid state heat pump (29), having a low temperature surface (32) thermally  
30 connected to the said measuring device (21), and a high temperature surface (34); and
  - a control circuit (30), connected to the said thermistor (28), to receive the said second signal ( $S_{TP}$ ), and to the said heat pump (29), to supply a control signal ( $I_C$ ) correlated with the said second signal ( $S_{TP}$ ).

6. Device according to Claim 5, characterized in that the said heat pump (29) comprises a Peltier cell.
7. Device according to Claim 5 or 6, characterized in that it comprises a heat sink element (35) placed in contact with the said high temperature surface (34) of the said heat pump (29).
8. Device according to any one of Claims 5 – 7, characterized in that the said controlled temperature ( $T_0$ ) is a constant temperature in the range from 5°C to 15°C.
9. Device according to any one of the preceding claims, characterized in that the said connecting portion (37) is made from a material having an essentially constant transmittance and negligible absorbance in the said first waveband ( $B_S$ ).
10. Device according to any one of the preceding claims, characterized in that the said connecting portion (37) is made from a material having an essentially constant transmittance in a temperature range from 30°C to 40°C.
11. Device according to any one of the preceding claims, characterized in that the said connecting portion (37) is made from a material chosen from the group consisting of high-density polyethylene, low-density polyethylene, and poly(4-methyl-1-pentene).
12. Device according to any one of the preceding claims, characterized in that it comprises filter means (38) interposed between the said measuring device (21) and the said connecting portion (37) of the said line (20).
13. Device according to Claim 12, characterized in that the said filter means (38) comprise a sheet of material which is essentially opaque to electromagnetic radiation outside a second waveband ( $B_P$ ) lying within the said first waveband ( $B_S$ ).
14. Device according to Claim 13, characterized in that the said second waveband ( $B_P$ ) is in the range from 8  $\mu\text{m}$  to 14  $\mu\text{m}$ .
15. Device according to Claim 13 or 14, characterized in that the said filter means (38) are made from germanium.
16. Device according to any one of Claims 12 – 15, characterized in that the said filter means (38) have one face (40) facing the said connecting portion (37) of the said line (20).
17. Device according to any one of the preceding claims, characterized in that the said first waveband ( $B_S$ ) is at least partially contained within the infrared radiation band (IR).
18. Device according to Claim 4, characterized in that it comprises a control unit (16a) associated with the said temperature sensor (19), for receiving the said first signal ( $V_B$ ) and for determining the said blood temperature ( $T_P$ ) according to a relation of the type:

$$T_P = F (V_B) + T_0$$

19. Device according to Claim 18, characterized in that the said relation is:

$$T_P = K * V_B + T_0$$

where K is an experimentally determined constant.

5 20. Control equipment for an extracorporeal blood circuit (2), in which the extracorporeal circuit (2) is connected to a blood purification machine (1; 45) and comprises an arterial branch (11) and a venous branch (13) connected to at least one blood treatment element (3; 3, 15a; 3, 15b; 45; 45, 15a; 45, 15b), the equipment (10) being  
10 characterized in that it comprises a non-invasive device (16) for measuring the blood temperature ( $T_P$ ) according to at least one of Claims 1 to 19.

21. Equipment according to Claim 20, characterized in that the non-invasive device (16) has a sensor (19) for measuring a first temperature ( $T_P$ ) of the blood leaving a patient (P) along the arterial branch (11) upstream of the said blood treatment element (3; 3, 15a; 3, 15b; 45; 45, 15a; 45, 15b), a control unit (16a) for regulating the blood temperature (T) as a function of the first temperature ( $T_P$ ) and a reference temperature ( $T_{SET}$ ), and a device  
15 (18) for regulating the blood temperature (T) which is connected to a portion (13a) of the venous branch (13) downstream from the said blood treatment element (3; 3, 15a; 3, 15b; 45; 45, 15a; 45, 15b).

22. Equipment according to Claim 21, characterized in that the said regulating device  
20 (18), is combined with the said portion (13a) to form a heat exchanger; the said control unit (16a) being connected to the said temperature regulating device (18).

23. Equipment according to Claim 21 or 22, characterized in that the said regulating device (18) comprises a line (18a) for conveying a fluid which can be heated to a temperature ( $T_F$ ) which lies within a specified range, approximately around 37° C.

25 24. Equipment according to one of Claims 21 to 23, characterized in that the said regulating device (18) has a seat (18b) for housing the said portion (13a) of the venous branch (13).

25. Equipment according to one of Claims 21 to 24, characterized in that the said  
30 extracorporeal circuit (2) is connected to a pump (12) to convey the blood along the extracorporeal circuit (2), the equipment (10) comprising a sensor (17) for detecting the operating state of the pump (12); the control unit (16a) keeping the temperature ( $T_F$ ) of the said fluid equal to the said predetermined temperature ( $T_{SET}$ ) when the pump (12) is not in operation.

26. Equipment according to one of Claims 21 to 25, characterized in that the said venous branch has a post-dilution node (15b); the said portion (13a) being located downstream of the said post-dilution node (15b).

27. Equipment according to any one of Claims 21 to 26, characterized in that the said  
5 blood treatment element (3; 3, 15a; 3, 15b) consists of a haemodialysis filter (3) comprising a blood compartment (5) and a dialysate compartment (6) within which a dialysate flows.

28. Equipment according to one of Claims 21 to 26, characterized in that the said blood  
10 treatment element (3; 3, 15a; 3, 15b) comprises a haemodialysis filter (3) comprising a blood compartment (5) and a dialysate compartment (6) within which a dialysate flows, and a pre- or post-dilution node (15a; 15b) for the introduction of a replacement fluid.

29. Equipment according to one of Claims 21 to 26, characterized in that the said blood treatment element (45; 45, 15a; 45, 15b) consists of a haemofiltration filter (45).

30. Equipment according to one of Claims 21 to 26, characterized in that the said blood  
15 treatment element (45; 45, 15a; 45, 15b) comprises a haemofiltration filter (45) and a pre- or post-dilution node (15a, 15b) for the introduction of a replacement fluid.

31. Equipment according to Claim 21, characterized in that the said control unit (16a) regulates the temperature (T) as a function of the first temperature ( $T_P$ ) and the reference temperature ( $T_{SET}$ ) at predetermined time intervals.

20 32. Equipment according to Claim 21 or 31, characterized in that the said control unit (16a) regulates the temperature (T) as a function of the difference between the first temperature ( $T_P$ ) and the reference temperature ( $T_{SET}$ ).



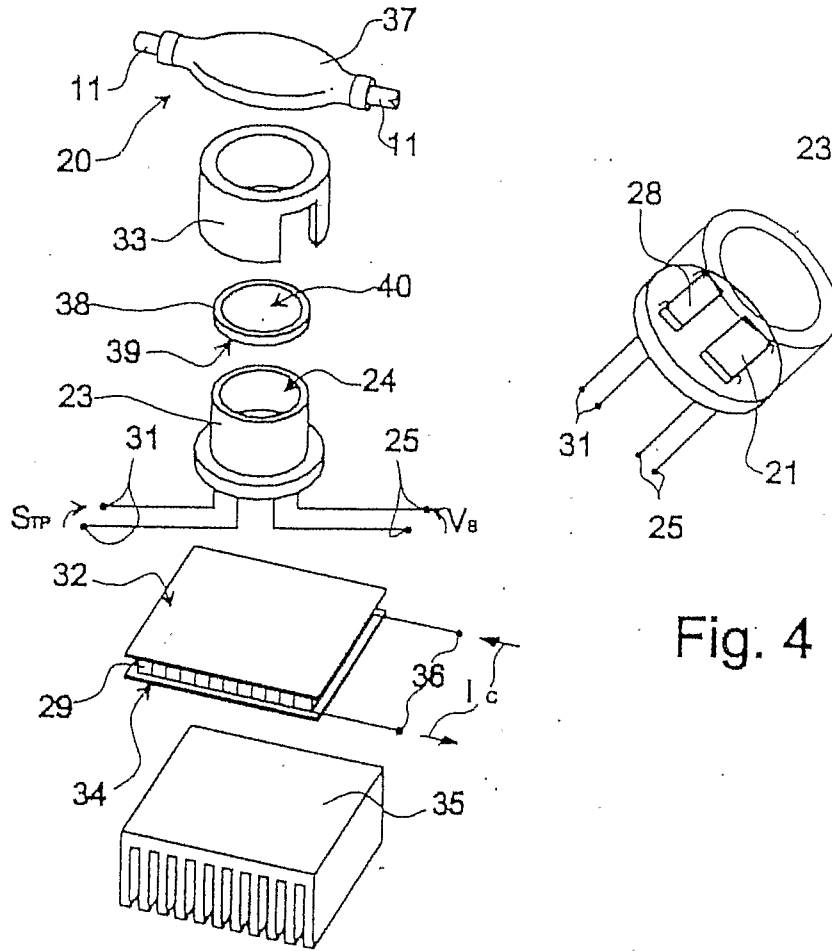


Fig. 3

Fig. 4

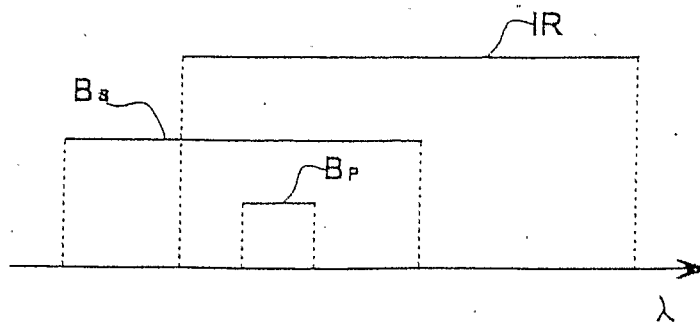


Fig. 5

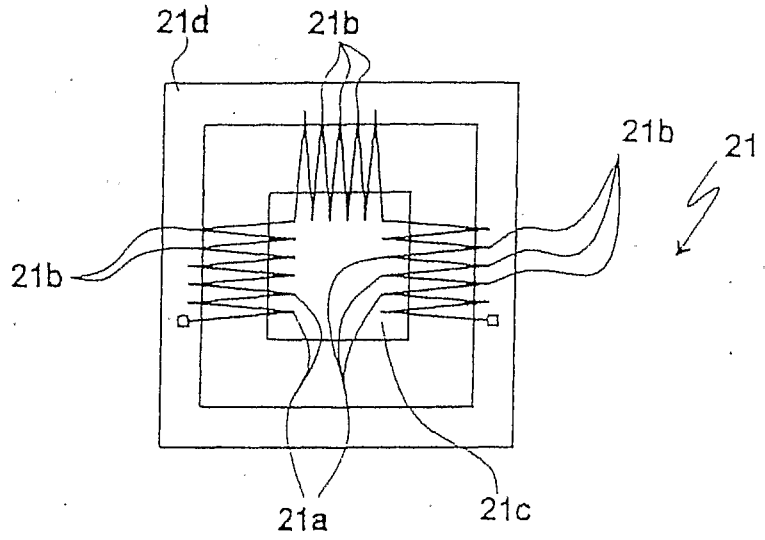


Fig. 6

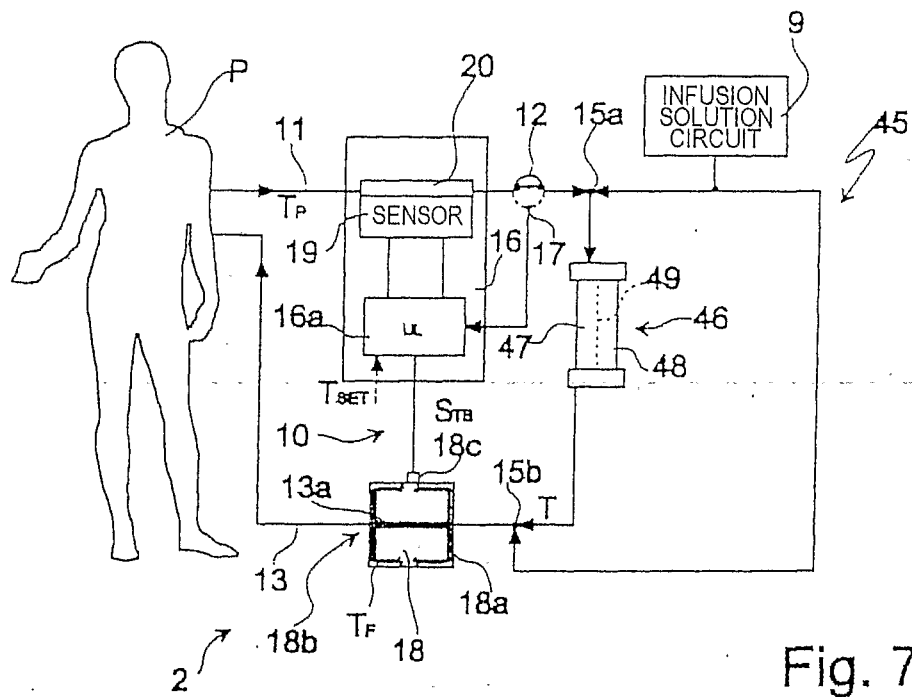


Fig. 7

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 02/05572

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61M1/16 G01K13/02 G01K1/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61M G01K G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 98 38953 A (FARIES DURWARD I JR ;MEDICAL SOLUTIONS INC (US); HEYMANN BRUCE (US) 11 September 1998 (1998-09-11) page 16 page 37 figure 11	1
A	EP 0 364 579 A (TERUMO CORP) 25 April 1990 (1990-04-25) page 8-10	1
	-/--	

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

## ° Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
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- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*&\* document member of the same patent family

Date of the actual completion of the international search

3 April 2003

Date of mailing of the international search report

14/04/2003

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 02/05572

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4 444 498 A (HEINEMANN STANLEY O) 24 April 1984 (1984-04-24) column 2, line 3-20 column 3, line 13-23 figure 3 -----	9-11

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Information on patent family members

International Application No

PCT/IB02/05572

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专利名称(译)	用于测量用于血液体外循环的回路中的血液温度的非侵入性装置，以及具有该装置的设备		
公开(公告)号	<a href="#">EP1458434A1</a>	公开(公告)日	2004-09-22
申请号	EP2002805865	申请日	2002-12-20
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IPC分类号	G01K13/02 A61B5/00 A61M1/14 A61M1/36 G01J5/04 G01K1/14 G01K11/00 G01K13/00 A61M1/16		
CPC分类号	G01J5/04 A61M1/367 A61M2205/3368 G01J5/0037 G01J5/061 G01J5/12 G01K1/143 G01K11/006		
优先权	MI2001002828 2001-12-28 IT		
其他公开文献	EP1458434B1		
外部链接	<a href="#">Espacenet</a>		

#### 摘要(译)

用于测量用于血液体外循环的回路中的血液温度的非侵入性装置 ( 16 ) 包括：线路 ( 20 ) ，其中从患者流出的血液流动 ( P ) ，以及温度传感器 ( 19 ) ，其连接到血液。所述线 ( 20 ) 设置有用测量电磁辐射强度的装置 ( 21 ) 。测量装置 ( 21 ) 面向线路 ( 20 ) 的连接部分或窗口 ( 37 ) ，其可通过第一波段 ( B→S ) 中的电磁辐射透射，并产生第一信号 ( V ? B ? ) 与第一频带 ( B ? S ) 中的电磁辐射相关联，因此，与在线 ( 20 ) 中流动的血液的温度相关。