

(12) UK Patent Application (19) GB (11) 2 344 892 (13) A

(43) Date of A Publication 21.06.2000

(21) Application No 9827697.5

(22) Date of Filing 16.12.1998

(71) Applicant(s)
Solartron Group Limited
(Incorporated in the United Kingdom)
Victoria Road, FARNBOROUGH, Hampshire,
GU14 7PW, United Kingdom

(72) Inventor(s)
Wojciech Konrad Kulczyk

(74) Agent and/or Address for Service
Reddie & Grose
16 Theobalds Road, LONDON, WC1X 8PL,
United Kingdom

(51) INT CL⁷
G01K 7/13

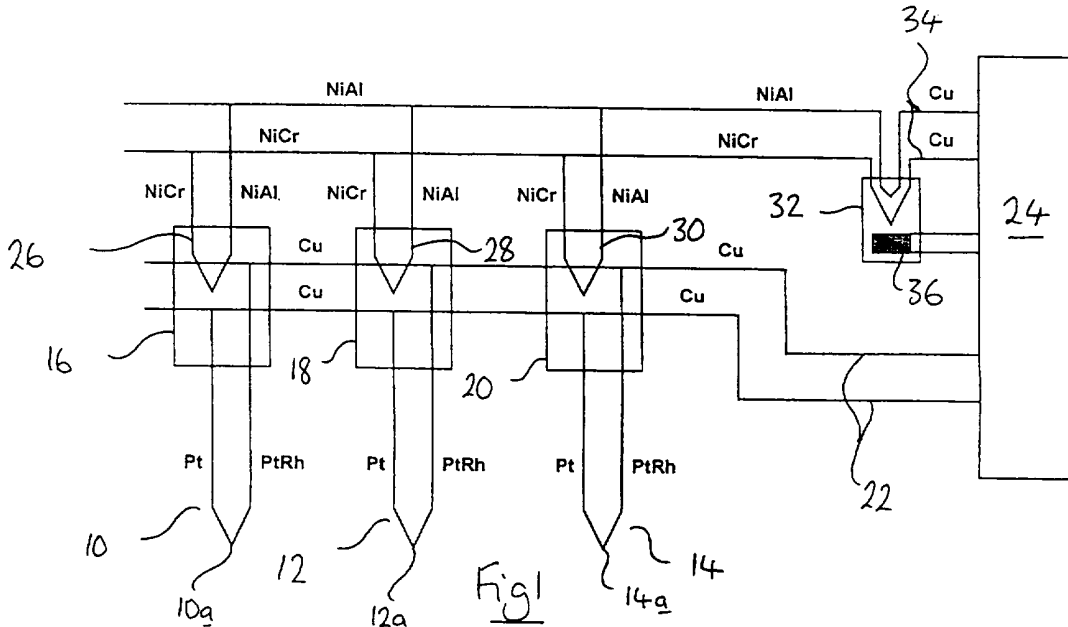
(52) UK CL (Edition R)
G1N NAAK NAHB N1A1 N1D13 N1D4 N3S1B

(56) Documents Cited
GB 1258645 A **US 5106203 A** **US 5046858 A**
US 4583867 A

(58) Field of Search
UK CL (Edition Q) **G1N NAAK NADCM NAHB NAHHK**
INT CL⁶ **G01D 1/02 , G01K 7/02 7/12 7/13**
ONLINE: WPI

(54) Abstract Title
Cold junction compensation for multiple thermocouples

(57) A system for measuring average temperature including a plurality of measurement thermocouples (10,12,14) connected in parallel to measurement apparatus (24) by two signal wires (22) of a material different to that of the measurement thermocouples (10,12,14). Compensation thermocouples (26,28,30) are located at the cold junctions (16,18,20) of the measurement thermocouples (10,12,14) and connected to the measurement apparatus (24).



GB 2 344 892 A

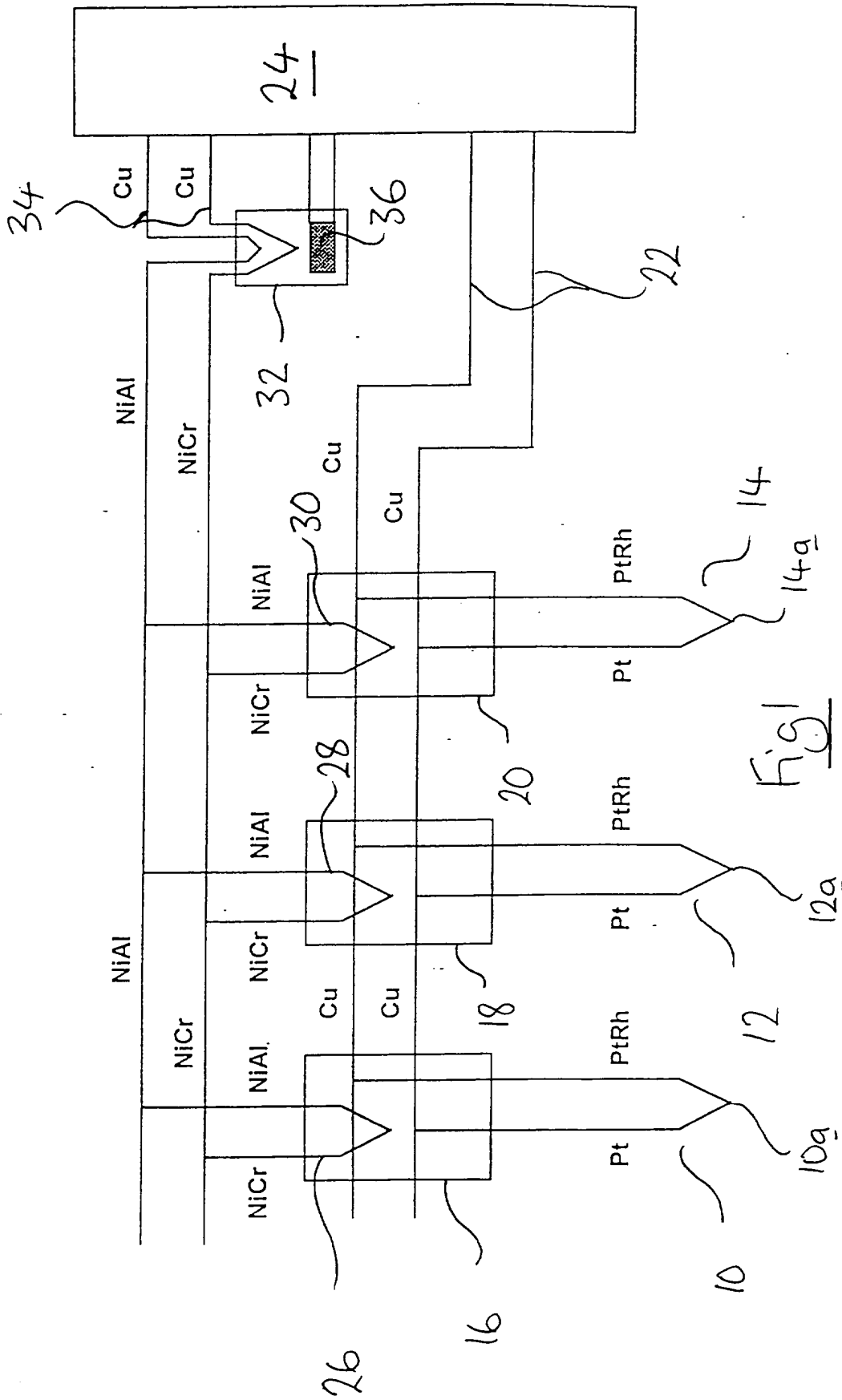


Fig 1

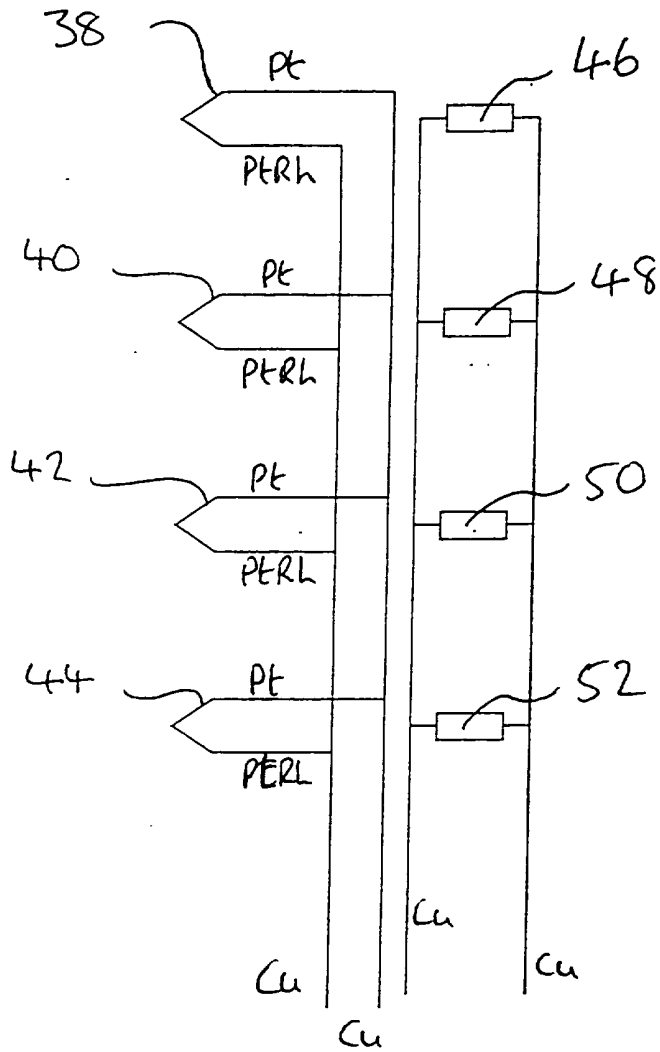


Fig 2

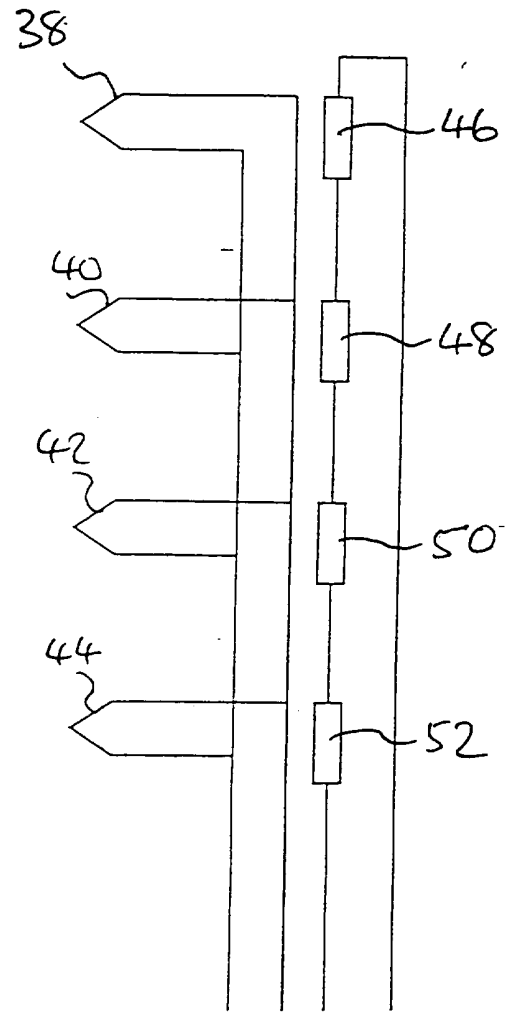


Fig 3

Cold Junction Compensation For Multiple Thermocouples

The present invention relates to a system for cold junction compensation for a plurality of thermocouples.

In some applications, such as temperature measurement in aero engines, the temperatures to be measured are in excess of those which can be tolerated by conventional NiCr/NiAl thermocouples (commonly referred to as K-type thermocouples). The total gas temperature (TGT) inside some new jet engines is above 1200C which is above the reliable operating limit for a K-type thermocouple. Because of this it is desirable to fabricate thermocouples for such high temperature applications from Platinum and Platinum-Rhodium (Pt/PtRh - commonly referred to as R-type thermocouples although other reference symbols are sometimes used). Such thermocouples have a much higher tolerance to high temperatures.

A thermocouple may be used in the measurement of temperature by measurement of a thermal voltage generated therein which is a function of the difference in temperature between its hot junction (usually located at the place where the temperature is to be measured) and its cold junction (which may be remote from the hot junction and which is at a known temperature).

A disadvantage of using R-type thermocouples is that the materials are relatively expensive. When connection is made to a remotely located cold junction it is practical to use low cost compensating cables to carry the voltage signal to measurement electronics, but only if the temperature is less than 100°C (beyond which such cables are unsuitable). At temperatures above this, which are common in aero engines, it is necessary to use thermocouple wires to carry the voltage signal to the

necessary measurement electronics, (situated usually at a safe distance from the extreme temperatures to be measured). In such situations the thermocouple installation becomes unacceptably expensive.

One solution to the problem of cost is to place the cold junction in a mounting head of the thermocouple - a relatively short distance from the hot junction and for example located on the exterior of an aero engine - which might be at a much lower temperature, and to connect the head back to the measurement electronics using inexpensive copper wire. The temperature at the cold junction must then be measured in order to provide a "compensation temperature" - ie. the thermocouple's cold junction temperature which can be used, together with the derived voltage signal to calculate the temperature of the hot junction, since the thermally generated voltage in a thermocouple is a function of the difference in temperature between its hot and cold junctions. For measurement of the temperature at the cold junction a conventional K-type thermocouple, or else a resistance temperature detector (RTD), such as a Platinum resistance thermometer (PRT) may be used.

However, some applications require the measurement of an average temperature from a plurality of thermocouple probes. In an aero engine, for example, there may be, typically, 8 to 17 thermocouple probes each of which is likely to contain at least two thermocouples. Since, according to the above-mentioned arrangement, each measurement (R-type) thermocouple has a pair of (e.g. copper) wires from the thermocouple head to the measurement electronics and each head must have at least one (K-type) thermocouple for measurement of the cold junction temperature at the head, which itself has a pair of wires extending back to the measurement electronics,

the number of connecting wires becomes substantial. In many applications space is at a premium and it is undesirable to have large bundles of wires conveying the appropriate signals from the thermocouple heads to the measurement electronics.

Accordingly, embodiments of the present invention aim to provide a system for cold junction compensation of multiple thermocouples in which the need for a large quantity of connecting wires is reduced.

The present invention is defined in the attached independent claims, to which reference should now be made. Preferred features may be found in the dependent claims. In one aspect, the invention provides a plurality of thermocouples of a first type for measuring an average temperature in a given environment, wherein each of the said thermocouples has a pair of thermocouple wires joined at their first ends in a thermojunction for location in said environment, and terminated at their second ends in one of a set of first thermocouple terminal heads, the first terminal heads being connected to each other by a first pair of signal wires for conveying a first average voltage signal to measurement apparatus, and a plurality of temperature sensitive devices for measuring the average temperature of the first terminal heads, there being at least one of said devices located in close proximity to each of the first terminal heads, the devices being connected to each other by a second pair of signal wires for conveying a second average voltage signal to measurement apparatus.

Preferred embodiments of the present invention will now be described by way of example only, with reference to the accompanying diagrammatic drawings in which:

Figure 1 shows, schematically, a system for providing cold junction compensation for a plurality of thermocouples, according to one embodiment of the present invention,

Figure 2 shows an alternative embodiment of the present invention, and

Figure 3 shows a further alternative embodiment.

Referring to Figure 1, this shows in schematic form a plurality of thermocouples 10, 12, 14 of Platinum/Platinum-Rhodium material. In use these thermocouples are housed in probes, either individually or else in pairs and are mounted for example in aero engines, such that the respective tips 10a, 12a, 14a will constitute hot junctions located inside the gas stream in the engine to measure the average total gas temperatures in the engine which might typically be of the order of 1200C to 1600C. At the other ends the thermocouple wires are terminated in heads 16, 18 and 20 mounted on the exterior of the engine at a much lower temperature which might typically be of the order of 300C to 400C. The thermocouples 10, 12, 14 are connected in parallel to copper wires 22 which extend to conventional analytical circuitry, represented by 24. The voltage across the copper wires 22 is generated thermally, as a result of a difference in temperatures between the tips and the heads, i.e. the hot junctions and cold junctions, of the thermocouples and is an average of the thermal voltage generated by the three thermocouples 10, 12, 14.

Knowing this voltage, which is measured by the analytical electronics 24, and knowing the temperature of the cold junctions located in the heads where the Pt or PtRh wires

are connected to the copper wires, permits calculation of the temperature at the tips.

To measure the average value of the temperature at the cold junctions - i.e. in the heads 16, 18 and 20, a second set of thermocouples is used, each thermocouple 26, 28, 30 being housed in the respective head 16, 18 and 20 as close as possible to the cold junctions between the Pt or PtRh and the Cu wire. This second set of thermocouples are connected in parallel by means of a harness (not shown) to one pair of NiCr and NiAl wires. Because the heads are mounted on the outside of the engine, and are therefore at much lower temperatures, the thermocouples 26, 28, 30 may be of K-type having wires of NiCr and NiAl which are much less expensive than the high temperature R-type thermocouples used inside the engine.

Because the K-type materials are less expensive they can be used to convey the signal back towards the analytical electronics 24. However, before connecting to the electronics 24 the NiAl and NiCr wires are connected to Cu wires at what becomes the cold junction 32 of the K-type thermocouples.

In order to know the average temperature of the cold junctions of the R-type thermocouples 10, 12, 14 - i.e. the temperatures in the heads 16, 18, 20 - it is necessary to know the thermally generated voltage across the return wires 34 from the K-type thermocouples, as well as the temperature at cold junction 32. The voltage is measured conventionally by the electronics 24. The cold junction (32) temperature may be measured for example by a conventional temperature measurement device such as a Platinum resistance thermometer 36.

Therefore the K-type thermocouples accurately measure the average temperature in the heads which is the average cold junction temperature of the R-type thermocouples 10, 12, 14. The potential across wires 22 is a function of the difference in temperature between the hot and cold junctions of the R-type thermocouples and so it is possible to obtain an accurate measurement of the average temperature at the tips of the R-type thermocouples - i.e. an average value for the total gas temperatures inside the aero engine.

Moreover, this is achieved without having to use expensive Pt and PtRh materials to carry the signal back to the analytical electronics. Furthermore, only two wires 22 are necessary to convey the average voltage signal from the R-type thermocouples to the electronics 24 and only two further wires 34 are needed to convey the average voltage signal from the K-type thermocouples to the electronics 24. Thus, cold junction compensation is provided without extensive use of costly materials and without the large numbers of bulky wires required by prior art arrangements.

Figure 2 shows an alternative embodiment, again in schematic form. Some labelling of the wires, and the analytical electronics, has been omitted from this diagram, for reasons of clarity.

Four R-type thermocouples 38, 40, 42, 44 are shown, but instead of K-type thermocouples this embodiment uses simple RTD elements 46, 48, 50, 52 to measure the average cold junction temperature of the R-type thermocouples. The RTDs may comprise Platinum resistance thermometers. They are connected in parallel, with each RTD being located in close proximity to its respective cold junction.

Figure 3 shows yet another variant in which the RTDs are used as in Figure 2, but this time they are connected in series.

Computer modelling of the arrangements described above has shown that the average hot junction temperatures may be measured with a high degree of accuracy.

CLAIMS

1. A thermocouple system comprising a plurality of thermocouples of a first type for measuring an average temperature in a given environment, wherein each of the said thermocouples has a pair of thermocouple wires joined at their first ends in a thermojunction for location in said environment, and terminated at their second ends in one of a set of first thermocouple terminal heads, the first terminal heads being connected to each other by a first pair of signal wires for conveying a first average voltage signal to measurement apparatus, and a plurality of first temperature sensitive devices for measuring the average temperature of the first terminal heads, there being at least one of said devices located in close proximity to each of the first terminal heads, the devices being connected to each other by a second pair of signal wires for conveying a second average voltage signal to measurement apparatus.

2. A system according to claim 1 wherein the first temperature sensitive devices comprise resistance temperature detectors (RTDs).

3. A system according to claim 2 wherein the RTDs comprise Platinum resistance thermometers (PRTs).

4. A system according to any of claims 1 to 3 wherein the first temperature sensitive devices are connected to the second pair of signal wires in parallel.

5. A system according to any of claims 1 to 3 wherein the first temperature sensitive devices are connected to the second pair of signal wires in series.

6. A system according to claim 1 wherein the first temperature sensitive devices comprise thermocouples of a second type, each of the said thermocouples having a pair of thermocouple wires joined at their first ends in a thermojunction for location in close proximity to one of said first terminal heads, and connected at their second ends to the thermocouple wires of all of the other thermocouples of the second type, by said second pair of signal wires, which second pair of signal wires is terminated in a second terminal head, said second terminal head being connected to a third pair of signal wires for connection to a measurement apparatus, and there being a second temperature sensitive device mounted in close proximity to said second terminal head, and connected to a fourth pair of signal wires for connection to said measurement apparatus.
7. A system according to claim 6 wherein the second temperature sensitive device comprises an RTD.
8. A system according to claim 7 wherein said RTD comprises a PRT.
9. A system according to any of the preceding claims wherein the thermocouples of the first type are constructed of Platinum and/or Platinum-Rhodium materials (Some examples of which are known as R-type thermocouples).
10. A system according to claim 6 wherein said thermocouples of the second type are of K-type and/or are constructed of Nickel-Aluminium and Nickel-Chromium.
11. A system according to any of the preceding claims wherein the first pair of signal wires is of copper.

12. A system according to claim 6 wherein the second pair of signal wires is of Nickel-Chromium and Nickel-Aluminium.

13. A system according to claim 6 wherein the third pair of signal wires is of copper.

14. A thermocouple system substantially as herein described with reference to the accompanying diagrammatic drawings.

15. A method of measuring an average temperature in a given environment, the method comprising locating thermal junctions of a plurality of thermocouples of a first type in said environment, and terminating thermocouple wires of said thermocouples in respective terminal heads, deriving a first average voltage signal from a first single pair of signal wires connected to all of the heads, deriving a second average voltage signal from a second single pair of signal wires connected to temperature sensitive devices, at least one of which is located in close proximity to each of the terminal heads, said second average voltage signal being indicative of the average temperature of the terminal heads, and calculating the average temperature in said environment based upon the average voltage signal from the thermocouples and on the average temperature of the terminal heads.

16. A method of measuring the temperature in a given environment the method being substantially as herein described with reference to the accompanying diagrammatic drawings.

Amendments to the claims have been filed as follows

CLAIMS

1. A system for measuring average temperature comprising a plurality of thermocouples (10,12,14,38,40,42,44) each
 5 being formed by a pair of thermocouple wires joined together at their first ends to form a hot junction (10a,12a,14a) with the other ends forming a cold junction (16,18,20) connected to measurement apparatus,

characterised in that the cold junctions (16,18,20) of
 10 the thermocouples (10,12,14,38,40,42,44) are connected to each other and to the measurement apparatus (24) by signal wire (22) of a different material to that of the thermocouple wires in a manner such that only two wires (22) connect the plurality of connected cold junctions
 15 (16,18,20) to the measurement apparatus (24) and a signal proportional to the average of the voltages generated by the thermocouples is supplied to the measurement apparatus (24),

and in that the device further comprises a plurality
 20 of further temperature sensitive devices (26,28,30,46,48,50,52) one at each of said cold junctions (16,18,20), the further temperature sensitive devices being connected to each other and to the measurement apparatus in a manner such a signal proportional to the average of the
 25 signals generated by the further temperature sensitive devices is supplied to the measurement apparatus (24).

2. A system according to claim 1 wherein the further temperature sensitive devices (26,28,30,46,48,50,52) are connected to each other in parallel.

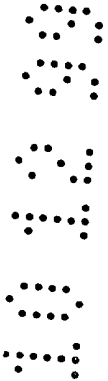
30 3. A system according to claim 1 wherein the further temperature sensitive devices (46,48,50,52) are connected to each other in series.

4. A system according to any preceding claim wherein the thermocouples (10,12,14,38,40,42,44) are connected to each other in parallel.
5. A system according to any preceding claim wherein the further temperature sensitive devices (46,48,50,52) comprise resistance temperature detectors (RTDs).
6. A system according to claim 5 wherein the RTDs comprise platinum resistance thermometers (PRTs) (46,48,50,52).
- 10 7. A system according to any of the preceding claims wherein the thermocouples (10,12,14,38,40,42,44) are constructed of Platinum and/or Platinum-Rhodium materials (some examples of which are known as R-type thermocouples).
- 15 8. A system according to any claims 1 to 4 wherein the further temperature sensitive devices (16,28,30) comprise compensation thermocouples.
- 20 9. A system according to claim 8 wherein the further temperature sensitive devices are thermocouples (26,28,30) of K-type and/or are constructed of Nickel-Aluminium and Nickel-Chromium.
10. A system according to any of the preceding claims wherein the signal wires (22) connecting the plurality of thermocouples (10,12,14,38,40,42,44) to each other and to the measurement apparatus are of copper.
- 25 11. A method of measuring the average temperature at the hot junctions of a plurality of thermocouples comprising:
determining the average voltage generated by the thermocouples by connecting the thermocouple cold junctions in parallel with each other and to calculation apparatus using signal wire of a different material to that of the
- 30

thermocouple wires, determining the average signal generated by a plurality of temperature sensitive devices, one at each of said cold junctions, by connecting the temperature sensitive devices to each other and to the calculation apparatus in a manner such that a signal proportional to the average of the signals generated by the temperature sensitive devices is supplied to the calculation apparatus, and calculating the average temperature of the thermocouple hot junctions by adding the temperature difference represented by the average thermocouple voltage supplied to the calculation apparatus to the temperature represented by the average temperature sensitive devices signal supplied to the calculation apparatus.

12. A system for measuring average temperature substantially as herein described with reference to the figures.

13. A method of measuring average temperature substantially as herein described with reference to the figures.





Application No: GB 9827697.5
Claims searched: 1 to 16

Examiner: Mark Bell
Date of search: 24 March 1999

**Patents Act 1977
Search Report under Section 17**

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK CI (Ed.Q): G1N (NAAK, NADCM, NAHB, NAHKK)
Int CI (Ed.6): G01D 1/02 G01K 7/02 7/12 7/13
Other: ONLINE:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 1258645 (TSENTRALNY NAUCHNO- ISSLEDOVATELSKY)	1,2
X	US 5106203 (NAPOLI ET AL) Fig. 3	1,4
X	US 5046858 (TUCKER) Fig.1	1-3,5,9
X	US 4583867 (GAUTHERET) Fig.2	1,5,10,12

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.