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(54) Title: A RESISTOR COMPRISING FIRST AND SECOND RESISTIVE ELEMENTS ON A COMMON COOLING SUBSTRATE

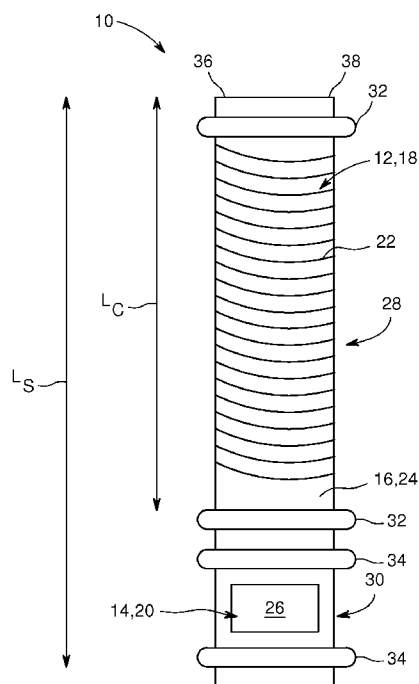


FIG. 1

(57) Abstract: A resistor (10) comprises first and second resistive elements (12, 14). Each of the first and second resistive elements (12, 14) is a different type (18, 20) of resistive element. The resistor (10) further comprises a cooling substrate (16) which is operatively couplable to a cooling mechanism (102). The same cooling substrate (16) is arranged to cool both of the first and second resistive elements (12, 14) when the cooling substrate (16) is operatively coupled to the cooling mechanism (102).

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A RESISTOR COMPRISING FIRST AND SECOND RESISTIVE ELEMENTS ON A COMMON COOLING SUBSTRATE

This invention relates to a resistor and a resistor assembly including a resistor.

It is known to use a resistor for a range of electrical applications, such as to create an electrical resistance in an electrical circuit which forms part of a power transmission network. Examples of power transmission networks are high voltage direct current (HVDC) power transmission networks and flexible AC transmission system (FACTS) power transmission networks.

According to a first aspect of the invention there is provided a resistor comprising first and second resistive elements, each of the first and second resistive elements being a different type of resistive element, the resistor further comprising a cooling substrate operatively couplable to a cooling mechanism, the same cooling substrate being arranged to cool both of the first and second resistive elements when the cooling substrate is operatively coupled to the cooling mechanism.

It will be understood that a “type of resistive element” in the context of the invention means a resistive element which uses a certain technology or takes a particular form so as to create an electrical resistance. A wire wound, foil, thick film and thin film are all examples of types of resistive elements.

It will also be understood that “to cool” in the context of the invention means to lower the temperature of the first and second resistive elements. This may mean to continually lower the temperature of the resistive elements and/or maintain the resistive elements at a predetermined temperature.

The resistor having first and second resistive elements that are each a different type of resistive element allows a single resistor to be used in an application with different electrical requirements, such as different electrical resistance, power and/or precision requirements.

Moreover, the resistor including a common cooling substrate arranged to cool both of the first and second resistive elements provides a means to regulate the temperature of the first and second resistive elements, while reducing the overall size and number of components of the resistor. In addition, the number of coolant joints between the resistor and a cooling mechanism is reduced thus minimising the risk of a cooling medium leakage occurring.

Preferably the first resistive element has a different resistance rating to that of the second resistive element.

The first and second resistive elements having differing resistance ratings further improves the suitability of the resistor to be used in an application which has differing electrical requirements.

Optionally the first resistive element surrounds the cooling substrate and the second resistive element is mounted onto the cooling substrate.

Such an arrangement permits the same cooling substrate to cool both of the first and second resistive elements in an effective manner.

In embodiments where one of the first and second resistive elements is a wire wound type of resistive element, the wire wound type resistive element may surround the cooling substrate, while another type of resistive element can be mounted on the cooling substrate. Wire wound type resistive elements typically include a housing that is surrounded by the resistive element, and such a housing may act as the cooling substrate. Thus the number of components is further reduced.

The first and second resistive elements and cooling substrate may be configured such that heat from the first resistive element is primarily transferred to a first portion of the cooling substrate positioned proximate to the first resistive element and that heat from

the second resistive element is primarily transferred to a second portion of the cooling substrate positioned proximate to the second resistive element.

Such a configuration facilitates optimum and efficient cooling of each of the resistive elements by the cooling substrate.

Optionally the first resistive element acts as a damping resistive element so as to create a damping resistance and the second resistive element acts as a grading resistive element so as to create a grading resistance.

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Such an arrangement permits the resistor to carry out two different resistance functions that are typically required in e.g. a power transmission network.

In an embodiment of the invention the first resistive element is a wire wound type of resistive element and the second resistive element is a film type of resistive element.

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The wire wound type of resistive element is formed by a resistive wire wound around an electrically non-conductive core, wherein the electrically non-conductive core comprises the cooling substrate. The configuration of the electrically non-conductive core may be designed or adapted at manufacture of the first resistive element to facilitate mounting or other attachment of the second resistive element.

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In some resistance applications, such as when a resistive element is acting as a damping resistive element, the loading on the resistive element is of a pulse power nature. A wire wound resistive element is more suited to this kind of loading than, for example, a thick film resistive element. Meanwhile, other resistance applications, such as when a resistive element is acting as a grading resistive element, the power requirements of the resistive element are high, e.g. 2kW. A film type, in particular a thick film type of resistive element is more suited to this kind of power requirement than, for example, a wire wound or foil type of resistive element.

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Accordingly, the resistor including a wire wound type of resistive element and a film type of resistive element permits the resistor to provide the required damping and grading resistances in a power transmission network.

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It will be understood that a thick film resistive element is a specific type of resistive element.

According to a second embodiment of the invention there is provided a resistor
10 assembly comprising a resistor as described herein above and a cooling mechanism operatively coupled to the cooling substrate.

The provision of a cooling mechanism provides a means for lowering the temperature of the cooling substrate and thereby cooling both of the first and second resistive
15 elements.

Optionally the cooling mechanism is or includes a fluid cooling medium. Such an arrangement provides an efficient and reliable means of lowering the temperature of the cooling substrate.

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Preferred embodiments of the invention will now be described, by way of non-limiting examples, with reference to the accompanying drawings in which:

Figure 1 shows a schematic view of a resistor according to a first embodiment of the
25 invention; and

Figure 2 shows a schematic view of a resistor assembly according to a second embodiment of the invention.

A resistor according to a first embodiment of the invention is shown in Figure 1 and is
30 designated generally by the reference numeral 10.

The resistor 10 includes first and second resistive elements 12, 14. Each of the first and second resistive elements 12, 14 are a different type of resistive element.

5 The resistor 10 further includes a cooling substrate 16 that operatively couplable to a cooling mechanism (not shown in Figure 1). The cooling substrate 16 is arranged to cool both of the first and second resistive elements 12, 14 when the cooling substrate 16 is operatively coupled to the cooling mechanism.

10 In the embodiment shown, the first resistive element 12 is a wire wound 18 type of resistive element and the second resistive element 14 is a thick film 20 type of resistive element.

The wire wound 18 type of resistive element is formed by a resistive wire 22 that is
15 wound around an electrically non-conductive core 24. The resistance wire 22 may be a nickel-chromium alloy wire and the electrically non-conductive core 24 may be made from a ceramic.

The thick film 20 type of resistive element is formed from a resistive layer 26 that is
20 deposited on an electrically non-conductive base (not shown). The resistance layer 26 may be a nickel-chromium alloy and the electrically non-conductive base may be made from a ceramic material.

In other embodiments of the invention (not shown), either, or both, of the first and
25 second resistive elements 12, 14 may be different types of resistive elements, for example each may be one of: a foil type or thin film type resistive element.

In the embodiment shown, the first resistive element 12 has a different resistance rating to that of the second resistive element 14. For example, the first resistive element 12
30 may have a resistance rating of 100Ω while the second resistive element 14 may have a resistance rating of $100k\Omega$.

In addition, the first resistive element 12 has a different power rating to that of the second resistive element 14. The power rating of the first resistive element 12 may be 2kW while the power rating of the second resistive element 14 may be 100W.

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The cooling substrate 16 is surrounded by the first resistive element 12, while the second resistive element 14 is mounted onto the cooling substrate 16. In particular, the cooling substrate 16 extends along the length L_C of the wire wound 18 type of resistive element so that the resistive wire 22 surrounds the electrically non-conductive core 24 and the cooling substrate 16. The thick film 20 type of resistive element is mounted onto the outside of the cooling substrate 16 via an adhesive.

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Moreover, the cooling substrate 16 extends beyond the length L_C of the wire wound 18 type of resistive element such that the cooling substrate 16 has a length L_S that is longer than that of the first resistive element 12.

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In the embodiment shown, the cooling substrate 16 is a single-piece substrate and is made from a ceramic material. The cooling substrate 16 may be formed from another type of material which has a thermal conductivity that permits sufficient cooling of the first and second resistive elements 12, 14. In one embodiment, the electrically non-conductive core 24 of the wire wound 18 type of resistive element may comprise the cooling substrate 16, the configuration of which may be adapted at the time of manufacture of the resistor element to facilitate mounting or other attachment of the second resistive element 14.

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The resistor 10 further includes two first resistive element electrical connections 32 for connecting the first resistive element 12 to an electrical circuit (not shown). The resistor 10 also includes two second resistive element electrical connections 34 for connecting the second resistive element 14 to an electrical circuit. The electrical circuit in each case may be the same electrical circuit, such as a thyristor circuit. The first and second resistive elements 12, 14 may instead be connectable to different electrical circuits.

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The cooling substrate 16 also includes an inlet 36 and an outlet 38 formed at the same end of the cooling substrate 16. The inlet 36 and outlet 38 are configured to be operatively coupled to a cooling mechanism so as to circulate a fluid cooling medium through the cooling substrate 16.

The inlet 36 and outlet 38 may be positioned elsewhere on the cooling substrate 16 but preferably one is positioned in the first cooling portion 28 and the other is positioned in the second cooling portion 30.

In the embodiment shown, the first resistive element 12 acts as a damping resistive element so as to provide a damping resistance to the electrical circuit connected thereto. The second resistive element 14 acts as a grading resistive element so as to provide a grading resistance, in particular a DC grading resistance, to the electrical circuit connected thereto.

In use, the cooling substrate 16 is operatively coupled to a cooling mechanism and each of the first and second resistive elements 12, 14 is connected to the or each electrical circuit via respective first and second resistive element electrical connections 32, 34.

Each of the first and second resistive elements 12, 14 provides an electrical resistance to the or each electrical circuit and in doing so the resistive elements 12, 14 generate heat.

The heat dissipated by each of the first and second resistive elements 12, 14 is transferred to the cooling mechanism via the cooling substrate 16. In particular, heat is transferred from the first resistive element 12 into the cooling substrate in the vicinity of the first resistive element 12 to the cooling mechanism, while heat from the second resistive element 14 is transferred into the cooling substrate 28 in the vicinity of the second resistive element to the cooling mechanism. In this way, the temperature of the

first and second resistive elements 12, 14 is regulated by the same, single cooling substrate 16.

A resistor assembly according to a second embodiment of the invention is shown in
5 Figure 2 and is designated generally by the reference numeral 100.

The resistor assembly 100 includes a resistor 10 as described herein above in relation to the first embodiment of the invention.

10 The resistor assembly 100 further includes a cooling mechanism 102 which is operatively coupled to the cooling substrate 16. In particular, the cooling mechanism 102 is operatively coupled to the inlet 36 and outlet 38 of the cooling substrate 16.

In the embodiment shown, the cooling mechanism 102 includes a fluid cooling medium
15 104 in the form of water. The fluid cooling medium 104 may instead be another type of liquid or it may be a gas.

In other embodiments of the invention (not shown) the cooling mechanism 102 may take another form, such as fins coupled to the cooling substrate 16 to form a heat sink.

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The cooling substrate 16 is further configured compensate for stray capacitance that is generated by one or both of the first and second resistive elements 12, 14. This is particularly useful when one of the resistive elements 12, 14 is being used to provide a DC grading resistance to the electrical circuit connected thereto.

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The resistor 10 is used as described herein above in relation to the first embodiment of the invention. Meanwhile, the cooling mechanism 102 pumps the fluid cooling medium 104 into the inlet 36 and out the outlet 38 so as to circulate the fluid cooling medium 104 through the cooling substrate 16.

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The fluid cooling medium 104 flows through the cooling substrate adjacent to each of the first and second resistive elements 12, 14 and thereby permits a transfer of heat from the resistive elements 12, 14 into the fluid cooling medium 104.

- 5 In particular, the fluid cooling medium 104 passes through the cooling substrate 16 under the wire wound type 18 resistive element, the substrate serving as the electrically non-conductive core 24 of the first resistive element 12 and thereby permits a transfer of heat from the first resistive element 12 into the fluid cooling medium 104. At the same time, the fluid cooling medium 104 passes through the cooling substrate 16
- 10 adjacent to the second resistive element 14 and thereby permits a transfer of heat from the thick film type 20 resistive element into the fluid cooling medium 104 via the cooling substrate 16. In the latter regard, the cooling substrate 16 acts as an intermediary cooling medium to the second resistive element 14.

CLAIMS:

1. A resistor comprising first and second resistive elements (12,14), each of the first and second resistive elements (12,14) being of a different type of resistive element, the resistor further comprising a cooling substrate (16) operatively couplable to a cooling mechanism, the cooling substrate (16) being arranged to cool both of the first and second resistive elements (12,14) when the cooling substrate (16) is operatively coupled to the cooling mechanism.
2. A resistor according to Claim 1, wherein the first resistive element (12) has a different resistance rating to that of the second resistive element (14).
3. A resistor according to Claim 1 or Claim 2, wherein the first resistive element (12) surrounds the cooling substrate (16) and wherein the second resistive element (14) is mounted onto the cooling substrate (16).
4. A resistor according to any preceding claim, wherein the first resistive element (12) acts as a damping resistive element so as to create a damping resistance and the second resistive element (14) acts as a grading resistive element so as to create a grading resistance.
5. A resistor according to any preceding claim, wherein the first resistive element (12) is a wire wound type of resistive element (18) and the second resistive element (14) is a film type of resistive element (20).
6. A resistor according to claim 5, wherein the wire wound (18) type of resistive element is formed by a resistive wire (22) wound around an electrically non-conductive core (24) and wherein the electrically non-conductive core (24) comprises the cooling substrate (16).

7. A resistor according to claim 6, wherein the configuration of the electrically non-conductive core (24) is adapted at manufacture of the first resistive element (12) to facilitate mounting or other attachment of the second resistive element (14).
8. A resistor assembly comprising a resistor according to any one of Claims 1 to 7, and a cooling mechanism (102) operatively coupled to the cooling substrate (16).
9. A resistor assembly according to Claim 8, wherein the cooling mechanism (102) includes a fluid cooling medium (104).

1/2

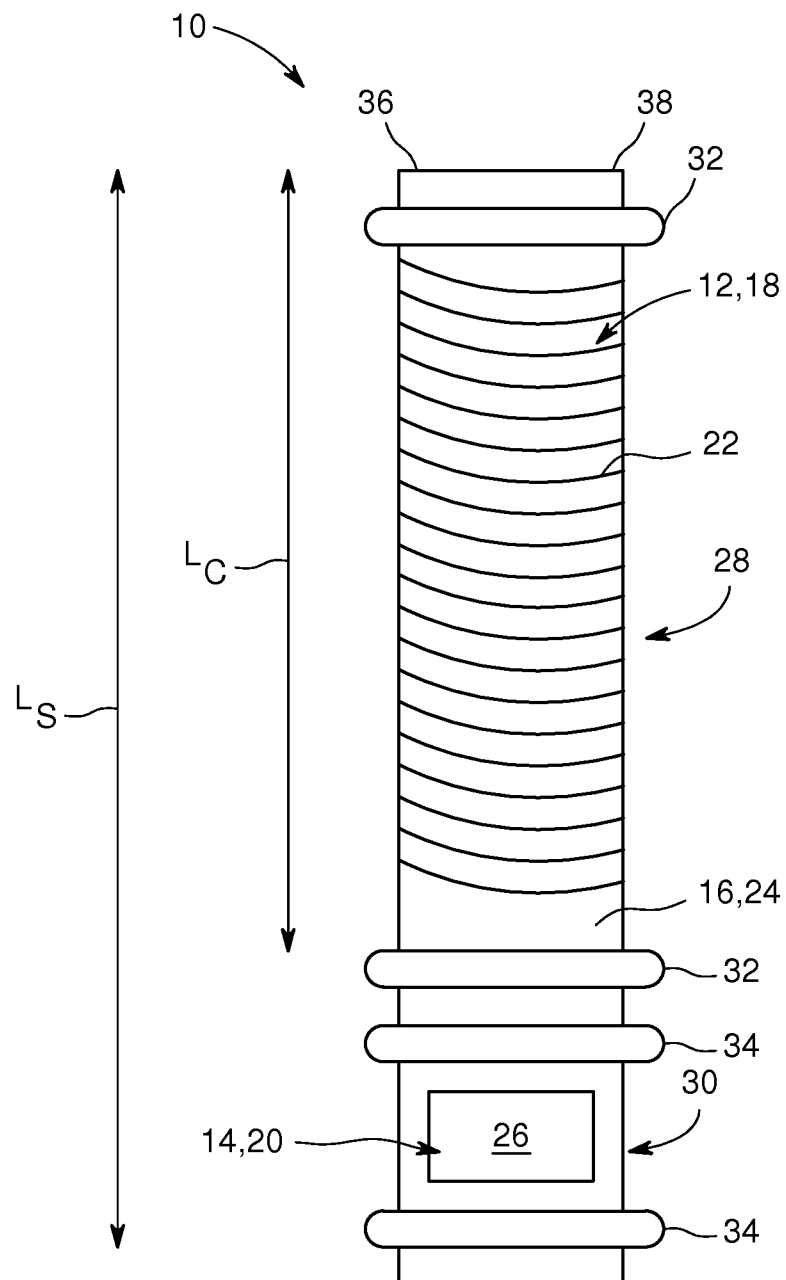


FIG. 1

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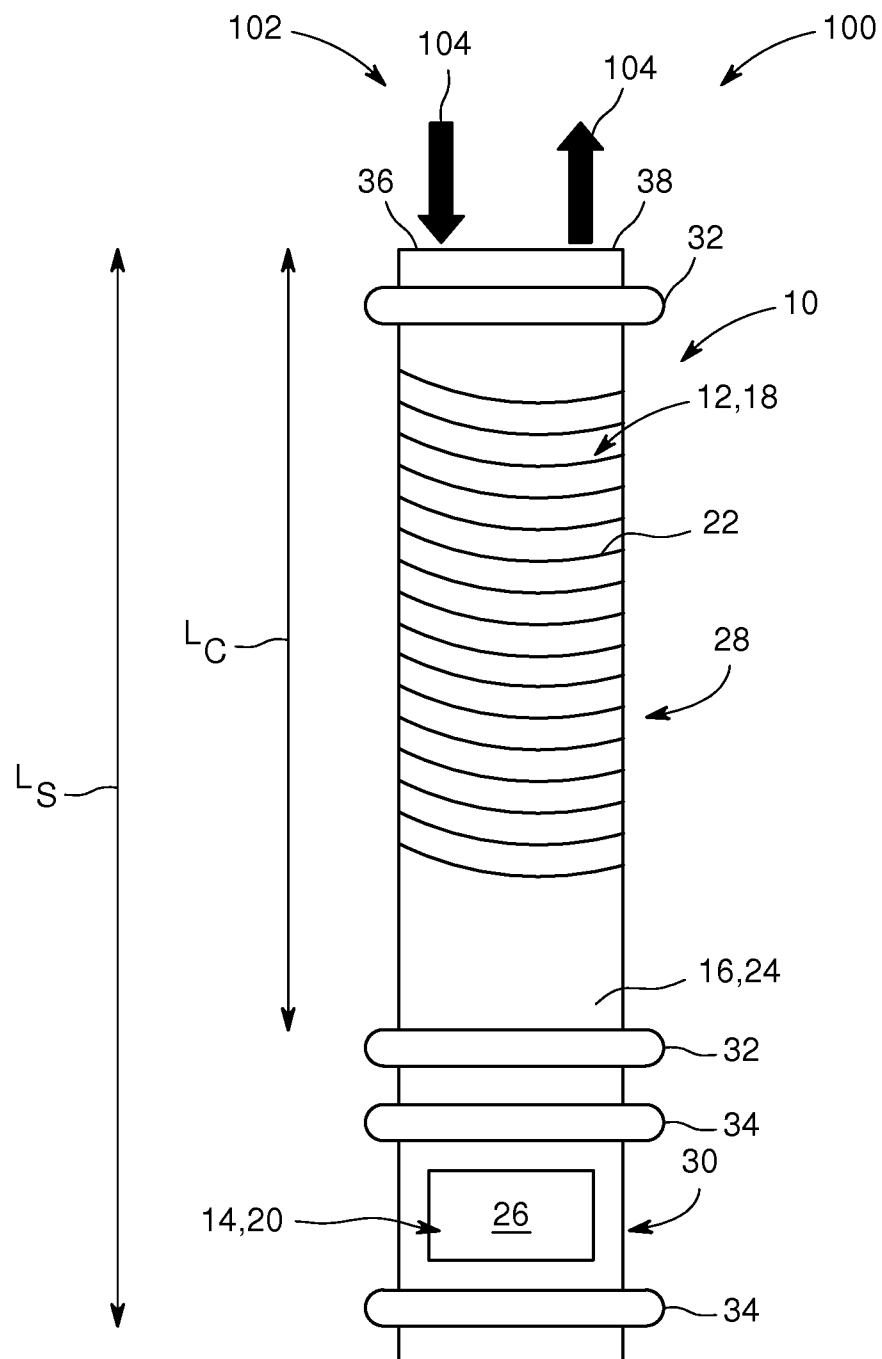


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/050610

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01C1/082 H01C13/02 H01C3/20
ADD.

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)

H01C

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 practicable, 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.
X A	GB 1 521 618 A (PLESSEY CO LTD) 16 August 1978 (1978-08-16) the whole document -----	1,2,4,8, 9 3,5-7
X A	US 2011/188165 A1 (EL FILALI KARIM [DE] ET AL) 4 August 2011 (2011-08-04) paragraphs [0020] - [0024], [0027], [0039]; figure 1 -----	1-7 8,9
A	US 5 353 005 A (SALANKI TIBOR [DE]) 4 October 1994 (1994-10-04) column 3, line 45 - column 4, line 38; figures 1-5 column 5, lines 27-45; figure 7 -----	1-9
A	GB 2 446 613 A (TYCO ELECTRONICS LTD UK [GB]) 20 August 2008 (2008-08-20) page 6, lines 4-7 - page 7, lines 13-32; figure 3 -----	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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