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(54) **A residual current device**

(57) A residual current device comprises a current transformer 40/42 having a plurality of primary windings W1, W2 each for connection to a respective conductor of an A.C. electricity supply and a secondary winding W3 into which a current is induced which is a function of the currents flowing in the primary windings, the current induced in the secondary winding initiating an action in response to a residual current above a predetermined threshold. Each of the primary and secondary windings is wound on a ferromagnetic element 40 or 42 of which at least the portion 40a, 40b, 42 bearing the winding has a substantially linear axis.

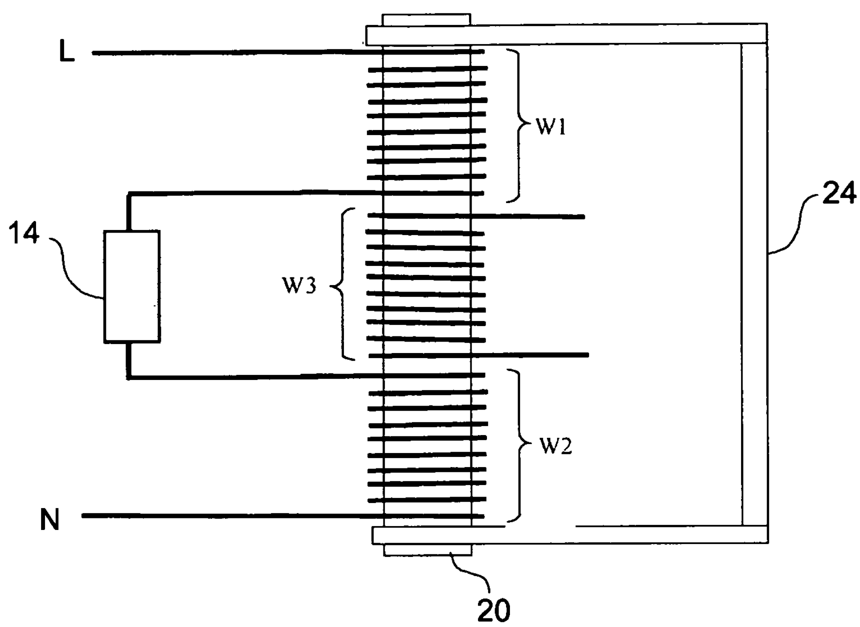

FIG. 3

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Description

[0001] This invention relates to a residual current device (RCD).

[0002] For the purposes of this specification, an RCD is defined as any device which can detect a residual current in an A.C. electricity supply, such as an A.C. mains, and initiate an action in response to such detection. Such action may be the opening of contacts in the supply conductors, or the raising of an alarm.

[0003] Detection of the residual current can be achieved by various means, but the most common means is by use of a differential current transformer. A conventional RCD used for an A.C. mains supply having live L, neutral N and earth E conductors is shown in Fig. 1.

[0004] The conventional RCD comprises a differential current transformer CT having a toroidal core 10, primary windings W1 and W2 connected respectively to the live L and neutral N conductors of the mains supply, and a secondary winding W3. The primary and secondary windings can comprise one or more turns, as required. A current flowing in either one of the primary windings W1, W2 will induce a current in the secondary winding W3, and when currents flow in both primary windings the current induced in the secondary winding W3 will be the vector sum of the currents individually induced therein by the primary windings. It should be noted that the secondary winding is also sometimes referred to as a sense winding because it senses the differential current in the primary windings. Under normal conditions, when contacts 12A, 12B in the live and neutral conductors L, N are closed, all of the current flowing from live L to the load 14 will flow back from the load to neutral N with the result that the currents I_L, I_N flowing in the live and neutral conductors respectively will be of equal magnitude. The primary windings W1, W2 are arranged on the core 10 such that when $I_L = I_N$ the current induced in the secondary winding W3 is zero.

[0005] However, under an earth fault condition, a residual current I_E will flow from one of the primary conductors to earth with the result that I_L no longer equals I_N and the vector sum of the currents induced in the secondary winding W3 by the currents I_L, I_N flowing in the primary windings W1, W2 will be greater than zero. Thus, a net current will flow in the secondary winding W3.

[0006] The net current flowing in the secondary winding W3 flows through the winding 16 of a solenoid-operated device (such as a permanent magnet relay, not shown) coupled to the contacts 12A, 12B in known manner. When the residual current exceeds a predetermined threshold, known as the residual operating current of the RCD, the net current induced in the secondary winding W3 will be sufficient to actuate the solenoid-operated device, this in turn opening the contacts 12A, 12B and disconnecting the electricity supply from the load 14.

[0007] Although described for a single phase supply, the circuit shown in Fig. 1 may be adapted to multiphase electricity supplies by providing more primary windings. In that case the net current flowing in the secondary winding will correspond to the vector sum of the currents individually induced by all the primary windings, and will be arranged to be zero in the absence of a residual current.

[0008] The foregoing is an example of a so-called voltage independent RCD, where the secondary current is applied directly or indirectly to the winding 16 of the solenoid-operated device. By contrast, in voltage dependent RCDs, part or all of the electronic circuitry is powered from the mains supply or an auxiliary voltage source, the output of the secondary winding being fed to an electronic circuit which processes the signal, and when the residual current exceeds a certain threshold, the electronic circuit causes the contacts 12A, 12B to open.

[0009] The toroidal differential CT as described above has been used for many years in RCD applications. It has the advantages of being simple, compact and reliable. However, a key disadvantage of the toroidal differential CT is that it does not lend itself to automated assembly or mass production. The primary and secondary windings must be fitted to each CT on an individual basis which precludes the possibility of assembling several CTs simultaneously. This problem can be compounded in cases where multiple primary turns are required to produce a desired secondary output from a lower differential current, or in cases where the primary conductors need to have a large cross sectional area to accommodate higher load current levels, etc. Factors such as core size and primary conductor size limit the number of turns that can be applied to the primary windings. This in turn limits the ampere turns available at the primary for differential current detection purposes. Due to these limiting factors, manufacturers are required to use very special core material in the toroidal CT in order to maximise the output produced in the secondary to enable voltage independent RCDs to detect relatively low residual current levels. This is not a significant problem for voltage dependent RCDs due to the availability of an energised electronic circuit to process the secondary current.

[0010] These factors explain why in general, the CT used in voltage independent RCDs is usually substantially larger and more expensive than that used in voltage dependent RCDs.

[0011] Assembly of toroidal differential CTs is a labour intensive operation which adds considerably to manufacturing time and cost of voltage independent RCDs. To minimise the cost of manufacturing toroidal differential CTs, many high volume manufacturers of such CTs have transferred production to locations where labour costs are low. This produces a temporary respite, but over time labour costs rise in all locations. It is generally accepted that automated assembly of the CT would be the optimum means of achieving low cost manufacture. Automated assembly would also provide for cost reductions for even relatively low volume production.

[0012] It is an object of the invention to provide a residual current device in which one or more of the above disadvantage is avoided or mitigated.

[0013] Accordingly, the present invention provides a residual current device comprising a current transformer having a plurality of primary windings each for connection to a respective conductor of an A.C. electricity supply and a secondary winding into which a current is induced which is a function of the currents flowing in the primary windings, the current induced in the secondary winding initiating an action in response to a residual current above a predetermined threshold, wherein each of the primary and secondary windings is wound on a ferromagnetic element of which at least the portion bearing the winding has a substantially linear axis.

[0014] Normally, as in the case of the embodiments to be described, the primary and secondary windings are arranged such that the net current induced in the secondary winding is zero in the absence of a residual current, so that the presence of a net induced current above a certain level, corresponding to the predetermined level of residual current, initiates the action. However, it is equally possible, in particular for so-called voltage dependent RCDs (see below), for the windings to be arranged such that a net induced current flows in the case of a zero residual current, and reduces as the residual current increases, so that a zero induced current would be indicative of the predetermined level of residual current. Other arrangements are also possible.

[0015] In one embodiment the windings are wound on at least two ferromagnetic elements forming a closed magnetic circuit.

[0016] However, in another embodiment the primary and secondary windings are wound on a common element having a linear axis.

[0017] Preferably the residual current device is a voltage independent type wherein the current induced in the secondary winding operates a solenoid to disconnect the electricity supply in response to a residual current above a predetermined level.

[0018] Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1, previously described, is a circuit diagram of a known RCD;

Fig. 2 is a circuit diagram of an embodiment of the invention; and

Fig. 3 shows a modification of the embodiment of Fig. 2;

Fig. 4(a) shows the current transformer of a second embodiment of the invention;

Fig. 4(b) is an end view of the current transformer of Fig. 4(a); and

Fig. 5 shows the current transformer of a third embodiment of the invention.

[0019] Referring now to the drawings, Fig. 2 shows an embodiment of the invention in which components the same or equivalent to those of Fig. 1 have the same reference numerals (the earth conductor E is not shown for convenience). In this embodiment the windings W1, W2 and W3 are wound on a common ferromagnetic core or former 20 having a substantially linear (i.e. non-curved) axis 22. The secondary winding W3 is placed axially between the primary windings W1, W2 and, as before, the windings are arranged on the core 20 such that when $I_L = I_N$ the current induced in secondary winding W3 is zero. Again, when a residual current exceeding a predetermined threshold is present, the net current induced in the secondary winding W3 and flowing in the winding 16 will be sufficient to actuate the solenoid-operated device to opening the contacts 12A, 12B and disconnect the electricity supply from the load 14. The turns ratios of W1, W2 and W3 can be arranged to achieve a desired secondary output for a given difference in primary currents.

[0020] The windings W1, W2 and W3 can be wound on a conventional bobbin or mandrill to provide for a conventional coil form as normally used on conventional transformer and solenoid windings. As a result, the individual windings can be produced by automated means which facilitates the production of numerous windings simultaneously. The simultaneous production of up to thirty windings by automated means is not uncommon. Furthermore, due to the rigidity of the wire in the primary windings, these windings can be formed and produced without the need for a bobbin.

[0021] The performance or efficiency of the RCD can be improved by closing the magnetic path with an external frame 24, as shown in Fig. 3.

[0022] Various arrangements can be used for the windings to optimise compactness or efficiency of the differential current transformer without deviating from the basic principle of operation. An example of an alternative arrangement is shown in Fig. 4.

[0023] In the arrangement of Fig. 4, the primary windings W1 and W2 are wound on a large diameter bobbin 26 having a linear axial bore 28. The secondary winding W3, shown in dashed lines in Fig. 4(a), is wound on a smaller diameter bobbin 30 also having a linear axial bore 32. A ferromagnetic core 34 is inserted coaxially into the bore 32 of the smaller diameter bobbin 30 and the latter is in turn inserted coaxially into the axial bore 28 of the large diameter bobbin 26.

[0024] It is a requirement for RCDs of the kind described above that when the RCD is operating at full load current under normal conditions, there should be negligible output from the secondary. This is verified in the product standards by what is sometimes referred to as a core balance test. This requires that the output from the CT secondary winding should not cause the RCD to trip for a balanced load current of up to six times the rated load current. Asymmetry in the winding arrangements of the CT can result in unwanted tripping under such conditions. The winding within a winding arrangement of Fig. 4 provides a convenient means of overcoming any asymmetry in the windings and meeting the core balance requirements. This is achieved by applying the desired maximum load current to W1 and W2, and physically moving the bobbin 30 axially within the bobbin 26 to the left or right of the mid point of the bobbin 26 so as to null or minimise any current induced into W3. Similar nulling can be achieved in any of the embodiments by moving one or more of the windings axially to optimise the nulling effect.

[0025] In the embodiment of Fig. 5 a ferromagnetic core is in the form of a closed magnetic circuit, in the present case a rectangle. The core is formed of a generally U-shaped ferromagnetic member 40 having opposite substantially parallel straight elongated limbs 40a, 40b and a substantially straight elongated member 42 extending between the free ends of the U-shaped member 40. Accordingly, all the elements 40a, 40b and 42 have respective linear axes. The base 40c of the U-shaped member 40 is also shown as being straight, but this is not necessary unless a winding is wound on it, which is not the case in the present embodiment. Therefore, the base 40c could be curved so that the member 40 as a whole assumes the traditional "U" shape with curved base. The members 40 and 42 could each comprise a single metal part, or comprise laminations stacked on top of each other.

[0026] In this embodiment the primary windings W1 and W2 are wound on the limbs 40a and 40b respectively, while the secondary winding W3 is wound on the member 42. Of course, the winding operations and placement of the windings on the respective members takes place before the straight member 42 is assembled to the member 40. The connections of the windings W1 to W3 into the overall circuit of the residual current device is as shown in Fig. 2.

[0027] As in the case of the conventional RCD of Fig. 1, the embodiments of the invention can be adapted to multiphase electricity supplies by providing more primary windings and arranging that the net current flowing in the secondary winding is zero in the absence of a residual current.

[0028] For example, in the case of the rectangular core 40/42 of Fig. 5, for a three phase application, one could place two phase windings on limb 40a, one phase winding on limb 40b, and the secondary winding on limb 40b or on member 42. For a three phase and neutral application, one could place two phase windings on limb 40a, one phase winding and the neutral winding on limb 40b, and the secondary winding on member 42.

[0029] In embodiments comprising a core and frame, one or more air gaps may be intentionally provided within the magnetic path comprising of the core and frame so as to facilitate calibration of the electromagnetic characteristics or performance of the transformer.

[0030] In all embodiments, it is not necessary that the various primary and secondary windings be directly wound onto the ferromagnetic elements of the final residual current device. It is alternatively possible to wind each winding on a temporary former, and then transfer the winding to the respective ferromagnetic element by sliding it off the former and onto the element. If the former is itself hollow, the transfer can be done without removing the winding from the former, simply by sliding the former over the ferromagnetic element.

[0031] It is also pointed out that although the invention has been described above in relation to voltage independent RCDs, it is equally applicable to voltage dependent RCDs, in which case the mains or auxiliary supply voltage may be used to process the output from the sense winding and or cause actuation of the tripping action in response to a differential current above a certain threshold.

[0032] The invention is not limited to the embodiments described herein which may be modified or varied without departing from the scope of the invention.

Claims

1. A residual current device comprising a current transformer having a plurality of primary windings each for connection to a respective conductor of an A.C. electricity supply and a secondary winding into which a current is induced which is a function of the currents flowing in the primary windings, the current induced in the secondary winding initiating an action in response to a residual current above a predetermined threshold, wherein each of the primary and secondary windings is wound on a ferromagnetic element of which at least the portion bearing the winding has a substantially linear axis.

2. A residual current device as claimed in claim 1, wherein the windings are wound on at least two ferromagnetic elements forming a closed magnetic circuit.

3. A residual current device as claimed in claim 2, wherein at least one winding is wound on a substantially straight limb of a first, generally-U-shaped, element, and at least one other winding is wound on a substantially straight element extending between the free ends of the limbs of the first element.

4. A residual current device as claimed in claim 1, wherein the primary and secondary windings are wound on a common element having a linear axis.

5. A residual current device as claimed in claim 1,

wherein the primary windings are wound on a common first element having an axial bore and the secondary winding is wound on a second element disposed at a selected axial position within the axial bore of the first element.

6. A residual current device as claimed in any preceding claim, wherein residual current device is a voltage independent type wherein the current induced in the secondary winding operates a solenoid to disconnect the electricity supply in response to a residual current above a predetermined level.

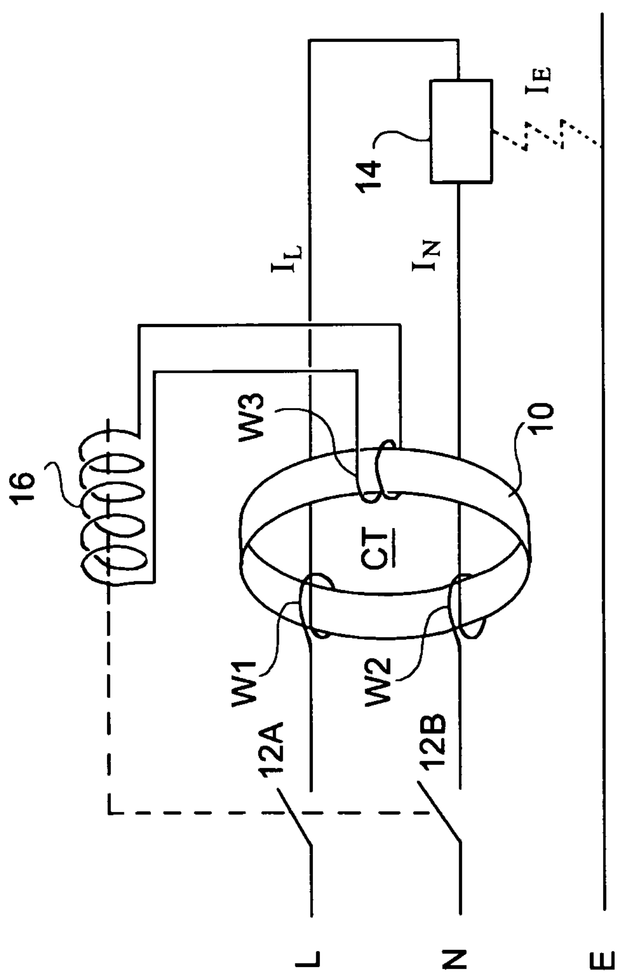

FIG. 1

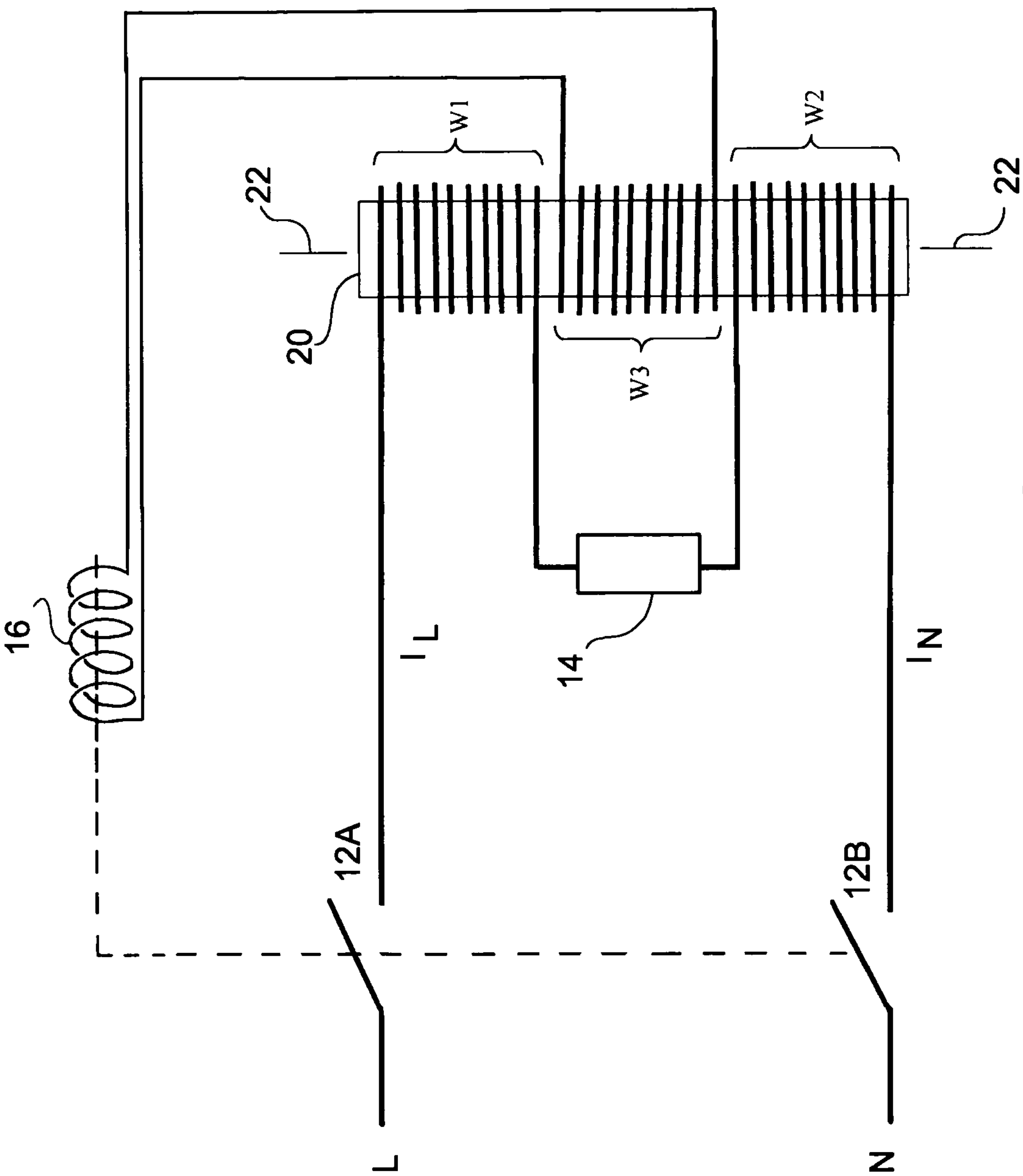

FIG. 2

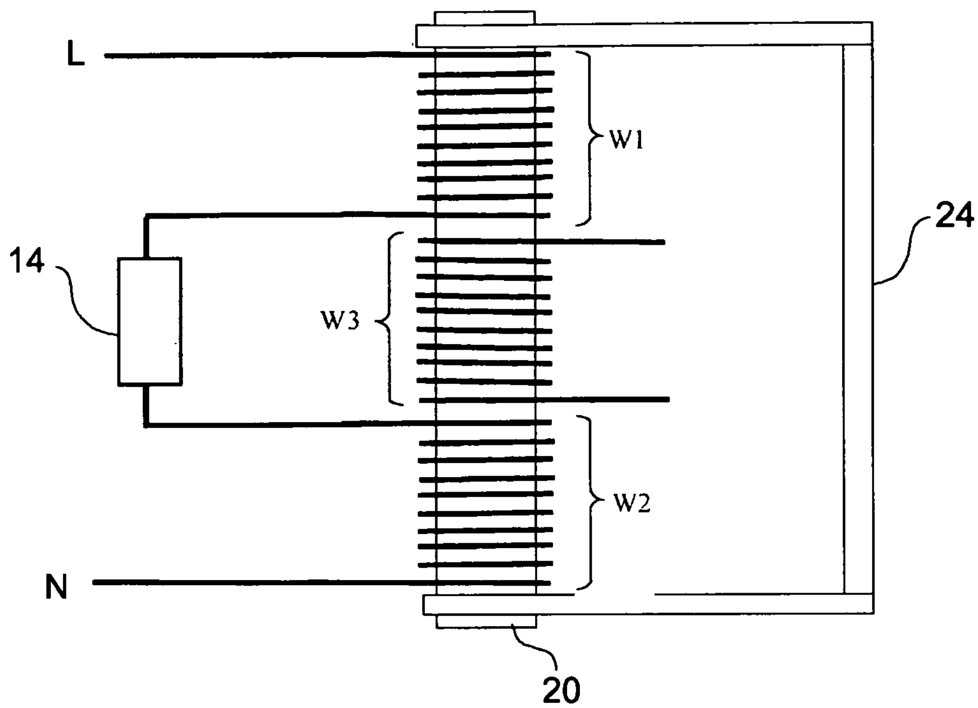

FIG. 3

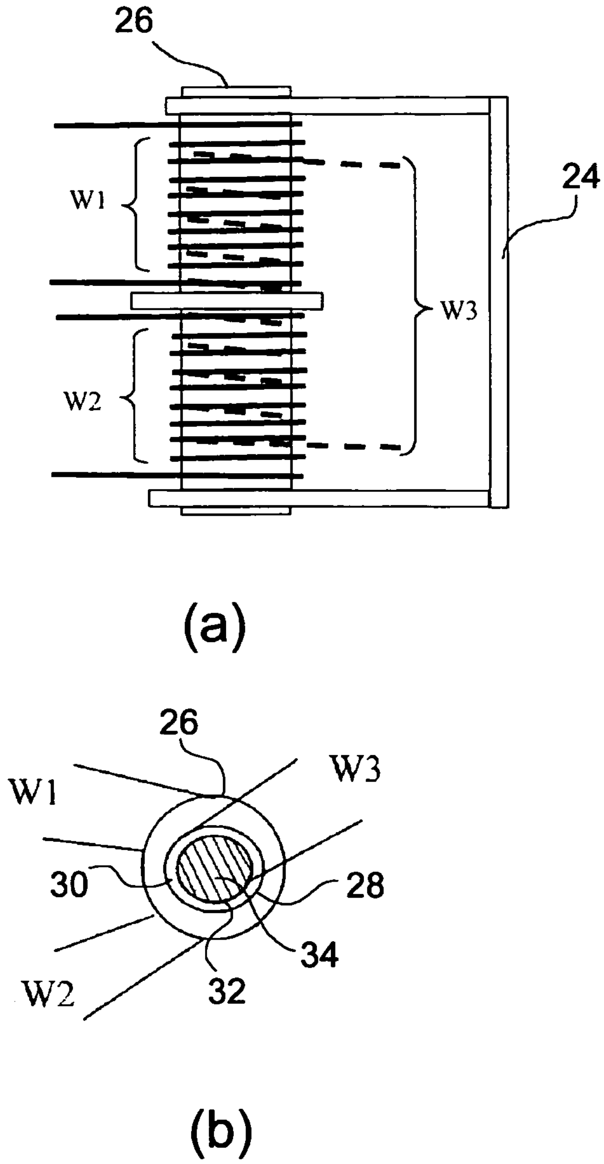

FIG. 4

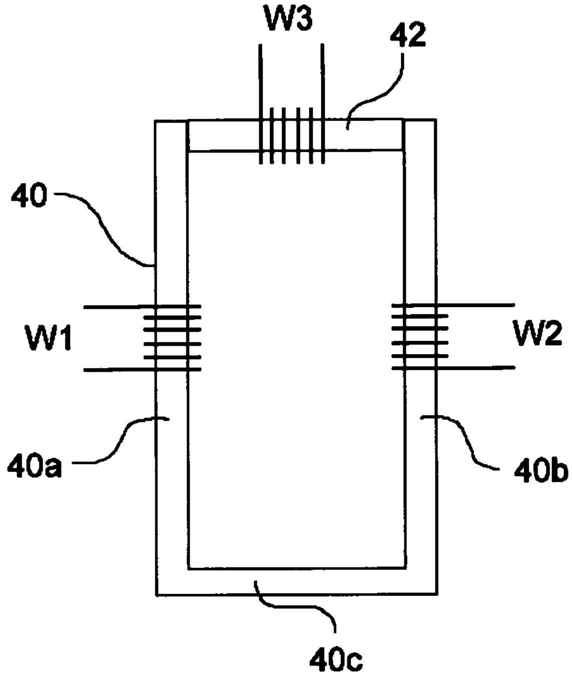

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 04 07 5652

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 01, 31 January 1996 (1996-01-31) & JP 7 240326 A (TOKIN CORP), 12 September 1995 (1995-09-12) * abstract *	1,2,4	H01F38/30
X	US 6 504 691 B1 (SHIMIZU HIDEKI ET AL) 7 January 2003 (2003-01-07) * abstract * * column 1, line 11 - line 45 * * column 8, line 53 - column 9, line 10; figures 3,7 *	1,2,4,6	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18 June 2004	Marti Almeda, R

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