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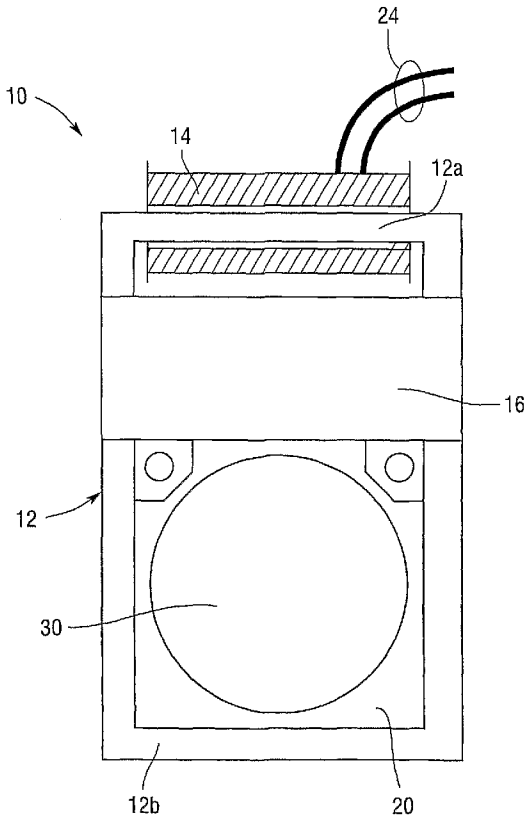
[Continued on next page]

(54) Title: A CURRENT TRANSFORMER INCLUDING A LOW PERMEABILITY SHUNT AND A TRIP DEVICE EMPLOYING THE SAME



(57) Abstract: A current transformer (10) comprises a coil (14) , a core (12) and a shunt member (16) . The core forms a magnetic circuit and has a first permeability. At least a portion of the core is encircled by the coil. The shunt member is coupled to the core and has a second permeability. The shunt member is continuous and forms a magnetically parallel path with the at least a portion of the core encircled by the coil . The current transformer may be incorporated in to a trip device.

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A CURRENT TRANSFORMER INCLUDING A LOW PERMEABILITY SHUNT AND A TRIP DEVICE EMPLOYING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates generally to electrical transformers and, more particularly, to current transformers. The invention also relates to trip devices including one or more current transformers.

Background Information

[0002] Trip devices are often used to protect the primary conductors of a power circuit. Trip devices typically include trip circuitry and a number of current transformers. The current transformers may supply electrical power to the trip circuitry and/or provide a signal to the trip circuitry corresponding to the amount of current flowing within the primary conductors. The current transformers interface with the primary conductors of the power circuit and transform a relatively high magnitude current flowing within the primary conductors into a relatively low magnitude current for use by the associated trip circuitry.

[0003] Figure 1 is a simplified illustration of a known current transformer 70 which includes a high permeability core 72 that surrounds a conductor 78 of a power circuit. A portion 72a of the core 72 passes through a coil 74 (which is shown cut away in Figure 1). A relatively small current, which may be supplied to other circuitry (not shown) via lead lines 75, is produced in the coil 74 when a relatively large current flows in conductor 78. The small current produced in the coil 74 is substantially linear over a wide operating range. Thus, as the current in conductor 78 increases, current in excess of that needed for sensing and power is generated in the coil 74. Undesirably, this excess current must be dissipated by the current transformer 70 or other devices (not shown).

[0004] Figure 2 is a simplified illustration of another known current transformer 80 incorporating shunt 86 with an air gap 88. The current transformer 80 includes a high permeability core 82 that surrounds the conductor 78 of the power circuit. A portion 82a of the core 82 passes through a coil 84 (which is shown cut away in Figure 2). When a relatively small current flows in conductor 78, the flux in the core 82 is low

enough to avoid saturation, and air gap 88 keeps the flux in the core 82 and out of the shunt 86. As the primary current increases, the flux in the core 82 (due to the presence of the parallel magnetic paths) reaches a point where it saturates. At this point, the increase in flux with the primary current is dramatically reduced. As a result, the increase of the current in coil 84 is reduced (i.e., no longer increases). Accordingly, the current response of the current transformer 80 is substantially non-linear and is generally determined by the shape and size of the air gap 88. The transformer 80 includes electrical leads 85 for supplying the current developed in the coil 84 to other circuitry (not shown).

[0005] Thus, a need exists for an improved current transformer. There also exists a need for an improved trip device including a current transformer.

SUMMARY OF THE INVENTION

[0006] These needs and others are met by the present invention, which is directed to a current transformer which comprises a coil, a core forming a magnetic circuit and having a first permeability, wherein at least a portion of the core is encircled by the coil, and a shunt member coupled to the core and having a different second permeability, wherein the shunt member is continuous and forms a magnetically parallel path with the at least a portion of the core encircled by the coil.

[0007] As another aspect of the invention, a trip device is for a protected circuit. The trip device comprises separable contacts structured to interrupt a current flowing in the protected circuit, an operating mechanism structured to open and close the separable contacts, a trip mechanism responsive to a first signal, the trip mechanism cooperating with the operating mechanism to trip open the separable contacts, a sensing device associable with the protected circuit, the sensing device outputting the first signal, a current transformer associable with the protected circuit, and a power supply circuit responsive to the second signal, the power supply circuit structured to provide power to at least one of the trip mechanism and the operating mechanism. The current transformer comprises a coil outputting a second signal responsive to the current flowing in the protected circuit, a core forming a magnetic circuit and having a first permeability and wherein at least a portion of the core is encircled by the coil,

and a shunt member coupled to the core and having a different second permeability, wherein the shunt member is continuous and forms a magnetically parallel path with the at least a portion of the core encircled by the coil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A full understanding of the invention can be gained from the following description of the preferred embodiments when read in conjunction with the accompanying drawings in which:

[0009] Figure 1 is a simplified illustration of a current transformer.

[0010] Figure 2 is a simplified illustration of another current transformer.

[0011] Figure 3 is an isometric view of a current transformer according to one embodiment of the invention.

[0012] Figure 4 is a simplified view of the current transformer of Figure 3.

[0013] Figure 5 is an isometric view of a shunt/core interface for the current transformer of Figure 3.

[0014] Figure 6 is an isometric view of a shunt/core interface for a current transformer according to another embodiment of the invention.

[0015] Figure 7 is a simplified view of a current transformer according to another embodiment of the invention.

[0016] Figure 8 is a simplified block diagram of a trip device incorporating a current transformer according to another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Directional phrases used herein, such as, for example, left, right, clockwise, counterclockwise, top, bottom, up, down, and derivatives thereof, relate to the orientation of the elements shown in the drawings and are not limiting upon the claims unless expressly recited therein.

[0018] As employed herein, the term "number" shall mean one or more than one.

[0019] As employed herein, the statement that two or more parts are "connected" or "coupled" together shall mean that the parts are joined together either directly or joined together through one or more intermediate parts. Further, as employed herein,

the statement that two or more parts are "attached" shall mean that the parts are joined together directly.

[0020] Figures 3 and 4 show a current transformer 10 including a core 12, a coil 14, and a shunt member 16. Two or more electrical lead wires 24 are structured to electrically connect the coil 14 to an external circuit (such as, for example, trip device circuitry) (not shown). In the current example, the core 12 is made of a number of laminae 18 (for example, without limitation, steel plates) which are coupled together to form a magnetic circuit. Although laminated in the current embodiment, it should be noted that the core 12 may be constructed in a different manner (e.g., may be solid) while remaining within the scope of the present invention. It should further be noted that the permeability of the core 12 is dependent upon the specific material chosen (here steel) and the specific manner of construction (here laminated).

[0021] As best seen in Figure 4, a portion 12a of the core 12 is encircled by the coil 14 (which is shown cut away in Figure 4). Another portion 12b of the core 12 is structured to surround a primary conductor 30 (as seen in Figure 4). As will be discussed in more detail in conjunction with Figure 8, the current transformer 10 may be used within a trip device 40 and the primary conductor 30 may be part of a circuit that the trip device 40 is tasked to protect. A clamp 20 may be used to secure the current transformer 10 to the primary conductor 30.

[0022] Continuing to refer to Figure 4, shunt member 16 is coupled to the core 12 and separates the core portion 12a encircled by the coil 14 and the core portion 12b surrounding the primary conductor 30. The shunt member 16 forms a magnetically parallel path with the core portion 12a that is encircled by the coil 14. Shunt member 16 is continuous (i.e., shunt member 16 does not include an air gap) and is coupled to the core 12 within the normal manufacturing tolerances (i.e., no special preparations are needed at the core/shunt interface). For example, in the current example, shunt member 16 is coupled to core 12 using a typical welding process. Although discussed above in the context of welding, it should be noted that shunt member 16 may be coupled to core 12 in any suitable manner (e.g., with a brazed connection; a clamp; a fastener; an adhesive; etc.).

[0023] In the current embodiment, shunt member 16 is constructed using a number of laminae 22 (e.g., steel plates which are laminated together) (Figure 3). Although

laminated in the current embodiment, it should be noted that shunt member 16 may be constructed in a different manner (e.g., may be solid) while remaining within the scope of the present invention. It should further be noted that the permeability of the shunt member 16 is dependent upon the specific material chosen (here steel) and the specific manner of construction (here laminated). In the current embodiment, the steel plates 22 used for shunt member 16 are chosen such that the permeability of the shunt member 16 is less than the permeability of the core 12.

[0024] The core 12 is structured to saturate when a suitably low primary current level flows within the primary conductor 30. Once core portion 12a saturates, flux linkage to core portion 12a is substantially reduced; an effect which will lower the rate of increase of secondary currents and power dissipation in the coil 14. For minimum power dissipation in the coil 14, saturation of core portion 12a should occur at primary currents just above those necessary to power an external device (e.g., a trip unit). Core portion 12b and shunt member 16 may be structured to saturate when a suitably higher primary current level flows within the primary conductor 30.

[0025] To facilitate the flow of flux through the shunt member 16, the shunt member 16 must be able to carry the core 12b saturation flux without itself saturating. Therefore, the cross-sectional area of the shunt member 16 is sized larger than the cross-sectional area of the core 12 and/or the shunt member 16 is constructed of a material having a suitably high saturation flux density. Additionally, the contact area of the contact points where the shunt member 16 is coupled to the core 12 is sized to have a greater cross-sectional area than the cross-sectional area of the core 12.

[0026] The shunt member 16 and the core 12 may be coupled edge-on-edge. Figure 5 is an example of an edge-on-edge core/shunt member interface 33 for the current transformer 10 of Figure 3. As shown in Figure 5, when the laminae 22 are coupled together, the shunt member 16 has a top surface 52, a bottom surface 51, and a number of side edges 53. Furthermore, when the laminae 18 are coupled together, the core 12 has a top surface 56, a bottom surface 55, and a number of side edges 57. For the edge-on-edge core/shunt interface illustrated in Figure 5, side edge 53a of shunt member 16 is coupled to side edge 57a of the core 12.

[0027] Alternatively, the shunt member 16 and the core 12 may be coupled side-on-edge. Figure 6 is an example of a side-on-edge core/shunt member interface 34 for a

current transformer 10′ (not shown) according to another embodiment. The shunt member 16 is coupled to the core 12 in such a manner that the bottom surface 51 (with respect to Figure 6) is in contact with edge 57a of the core 12. Although discussed in the context of edge-on-edge and side-on-edge coupling, it should be noted that other arrangements (for example, a side-on-side arrangement) are within the scope of the present invention.

[0028] Figure 7 is a simplified view of a current transformer 10″ according to another embodiment. In this embodiment, the current transformer 10″ includes a number of joining members 28a, 28b interleaved with the shunt member 16 and the core 12 at the contact area between the shunt member 16 and the core 12. As illustrated in Figure 7, joining member 28a is exemplary of a joining member that conforms to fit between the core 12 and the shunt member 16, whereas joining member 28b is exemplary of a joining member which is a simple slab placed between the core 12 and the shunt member 16. It should be noted that other arrangements may be used for the joining members 28a, 28b while remaining within the scope of the present invention. In the current embodiment, the joining members 28a, 28b are constructed of a composite material having a permeability that is less than the permeability of the core 12 and the permeability of the shunt member 16.

[0029] Figure 8 shows a trip device 40 which incorporates a current transformer 10 as shown in Figure 1. The trip device 40 includes a number of separable contacts 43, an operating mechanism 44, and a trip mechanism 46. Trip devices are well known. Examples of trip devices may be found in U.S. Patent No. 6,144,271 to Mueller et al., U.S. Patent No. 6,850,135 to Puskar et al., and U.S. Patent No. 5,943,204 to Jones et al., all of which are incorporated herein by reference. The trip device 40 may also include other components (e.g., without limitation, a processing circuit) (not shown).

[0030] The trip device 40 is illustrated in conjunction with a protected circuit which, in the current example, includes a primary power source 36, a load 38, and a primary conductor 30. Typically, the primary power source 36 provides power to the load 38 via the primary conductor 30.

[0031] The separable contacts 43 are structured to connect and/or isolate the primary power source 36 from the load 38 in response to the operating mechanism 44. More specifically, separable contacts 43 are structured to allow current flow from the

primary power source 36 to the load 38 if a trip condition does not exist and to interrupt current flow from the primary power source 36 to the load 38 if a trip condition exists.

[0032] A sensing device 42 is associated with primary conductor 30 such that when a current flows in primary conductor 30, a signal is generated in the sensing device 42. This signal is communicated to the trip mechanism 46, which in response, determines whether a trip condition exists (e.g., whether the current flowing in the primary conductor 30 has exceeded a predetermined threshold). If a trip condition exists, the trip mechanism 46 produces a trip signal which is communicated to the operating mechanism 44.

[0033] In response to the trip signal, operating mechanism 44 is structured to open the separable contacts 43 as is well known.

[0034] The current transformer 10 is also associated with primary conductor 30 such that when a current flows in primary conductor 30, a current is generated in the coil 14 (Figure 1) of the current transformer 10. The current generated in the coil 14 is supplied to a power supply circuit 48. The power supply circuit 48 is structured to condition the current supplied by current transformer 10 and to provide power to the other components (e.g., without limitations, trip mechanism 46) of the trip device 40.

[0035] Although discussed in the context of supplying current to the power supply circuit 48, it should be apparent that the current transformer 10 may be used in another capacity, for example, as a power transducer, as a frequency sensor, etc. For example, current transformer 10 may be used as a power transducer to replace sensing device 42 for sensing the current flowing in primary conductor 30 and to communicate a signal in response thereto to the trip mechanism 46. As a further example, current transformer 10 may be used for system frequency determination using a zero crossing detector.

[0036] Additionally, although discussed in context of the embodiment of current transformer 10 as shown in Figure 1, it should be apparent that the trip device 40 may incorporate any of the current transformers 10, 10′ (not shown), 10″ while remaining within the scope of the present invention.

[0037] Furthermore, although discussed in the context of a single phase protected circuit, it should be apparent that the present teaching can be adapted for use with a

multi-phase protected circuit while remaining within the scope of the present invention.

[0038] While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the claims appended and any and all equivalents thereof.

1. A current transformer (10) comprising:

a coil (14);

a core (12) forming a magnetic circuit and having a first permeability, wherein at least a portion (12a) of said core (12) is encircled by said coil (14); and

a shunt member (16) coupled to said core (12) and having a different second permeability, wherein said shunt member (16) is continuous and forms an electrically parallel path with said at least a portion (12a) of said core (12) encircled by said coil (14).

2. The current transformer (10) of Claim 1 wherein said core (12) is structured to surround a primary conductor (30) operable to carry a primary current.

3. The current transformer (10) of Claim 2 wherein said shunt member (16) and said at least a portion (12a) of said core (12) encircled by said coil (14) are structured to saturate at a first primary current level; and wherein at least another portion (12b) of said core (12) is structured to saturate at a second primary current level, said second primary current level being less than said first primary current level.

4. The current transformer (10) of Claim 1 wherein a cross-sectional area of said shunt member (16) is greater than a cross-sectional area of said core (12).

5. The current transformer of Claim 1 wherein said shunt member (16) is coupled to said core (12) at a number of contact points; wherein each of said contact points has a contact area with a cross-sectional area that is greater than a cross-sectional area of said core (12).

6. The current transformer (10) of Claim 1 wherein said shunt member (16) is coupled to said core (12) by at least one of a weld, a brazed connection, a clamp, a fastener, and an adhesive.

7. The current transformer (10) of Claim 1 wherein said shunt member (16) and said core (12) are coupled edge-on-edge.

8. The current transformer (10) of Claim 1 wherein said shunt member (16) and said core (12) are coupled side-on-edge.

9. The current transformer (10) of Claim 1 wherein said first permeability is greater than said different second permeability.

10. The current transformer (10) of Claim 1 wherein said core (12) comprises a joining member (28a,28b) interleaved with said shunt member (16) and said core (12) at least at a contact area between said shunt member (16) and said core (12), said joining member (28a,28b) having a different third permeability.

11. The current transformer (10) of Claim 10 wherein said first permeability is greater than said different third permeability and said different third permeability is greater than said different second permeability.

12. A trip device (40) for a protected circuit (30, 36, 38), said trip device (40) comprising:

separable contacts (43) structured to interrupt a current flowing in said protected circuit (30, 36, 38);

an operating mechanism (44) structured to open and close said separable contacts (43);

a trip mechanism (46) responsive to a signal, said trip mechanism (46) cooperating with said operating mechanism (44) to trip open said separable contacts (43); and

a current transformer (10) associable with said protected circuit (30, 36, 38), said current transformer (10) comprising:

a coil (14) outputting said signal responsive to said current flowing in said protected circuit (30, 36, 38),

a core (12) forming a magnetic circuit and having a first permeability and wherein at least a portion (12a) of said core (12) is encircled by said coil (14); and

a shunt member (16) coupled to said core (12) and having a different second permeability, wherein said shunt member (16) is continuous and forms an electrically parallel path with said at least a portion (12a) of said core (12) encircled by said coil (14).

13. The trip device (40) of Claim 12 wherein said core (14) is structured to surround a primary conductor (30) of said protected circuit (30, 36, 38).

14. The trip device (40) of Claim 13 wherein said shunt member (16) and said at least a portion (12a) of said core (12) encircled by said coil (14) are structured to saturate at a first primary current level and wherein at least another portion (12b) of said core (12) is structured to saturate at a second primary current level, said second primary current level being less than said first primary current level.

15. The trip device (40) of Claim 12 wherein a cross-sectional area of said shunt member (16) is greater than a cross-sectional area of said core (12).

16. The trip device (40) of Claim 12 wherein said shunt member (16) is coupled to said core (12) at a number of contact points; and wherein each of said contact points has a contact area with a cross-sectional area that is greater than a cross-sectional area of said core (12).

17. The trip device (40) of Claim 12 wherein said shunt member (16) is coupled to said core (12) by at least one of a weld, a brazed connection, a clamp, a fastener, and an adhesive.

18. The trip device (40) of Claim 12 wherein said shunt member (16) includes a number of laminae (22) coupled together, said shunt member (16) having a top surface, a bottom surface, and a number of side edges; and wherein said core (12) includes a number of laminae (18) coupled together, said core (12) having a top surface, a bottom surface, and a number of side edges; and wherein one of said side edges of said shunt member (16) is coupled to one of said side edges of said core (12).

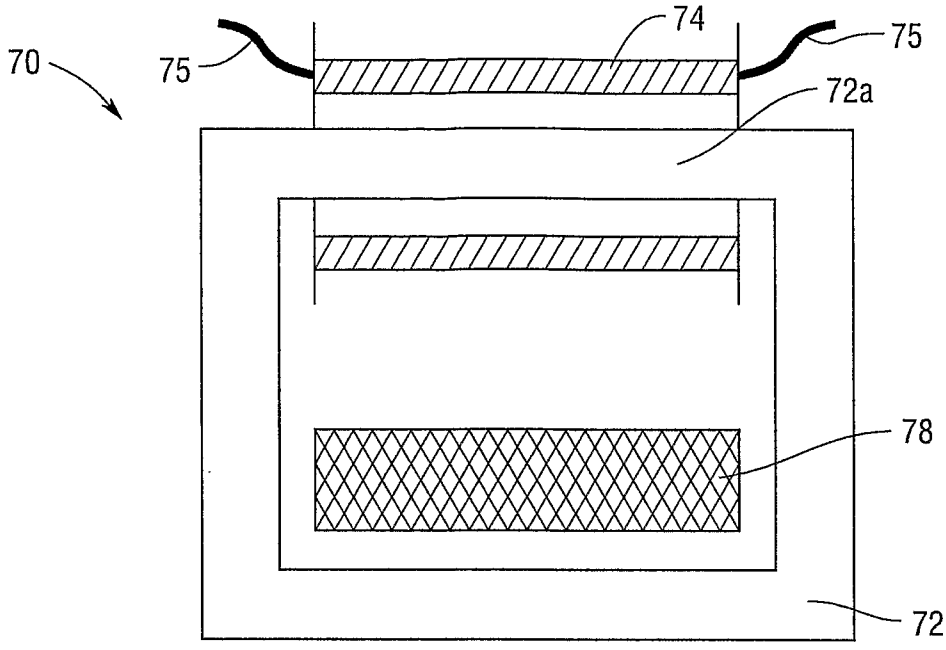
19. The trip device (40) of Claim 12 wherein said shunt member (16) includes a number of laminae (22) coupled together, said shunt member (16) having a top surface, a bottom surface, and a number of side edges; and wherein said core (12) includes a number of laminae (18) coupled together, said core (12) having a top surface, a bottom surface, and a number of side edges; and wherein one of said bottom surface and said top surface of said shunt member (16) is coupled to one of said side edges of said core (12).

20. The trip device (40) of Claim 12 wherein said shunt member (16) includes a number of laminae (22) coupled together, said shunt member (16) having a top surface, a bottom surface, and a number of side edges; and wherein said core (12) includes a number of laminae (18) coupled together, said core (12) having a top surface, a bottom surface, and a number of side edges; and wherein one of said bottom surface and said top surface of said core (12) is coupled to one of said side edges of said shunt member (16).

21. The trip device (40) of claim 12 wherein said first permeability is greater than said second permeability.

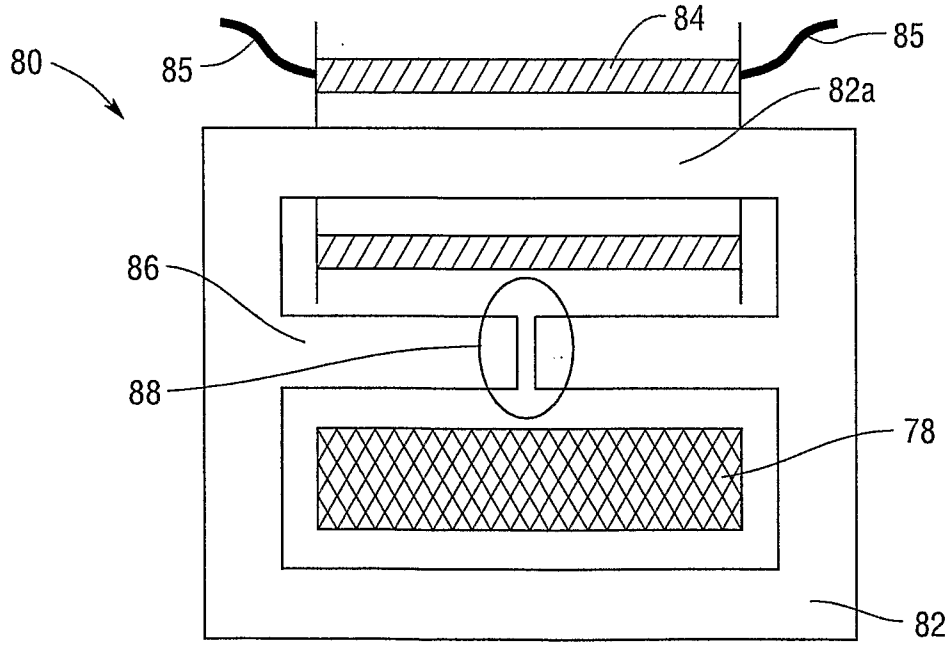
22. The trip device (40) of claim 12 wherein said core comprises a joining member (28a, 28b) interleaved with said shunt member (16) and said core (12) at least at a contact area between said shunt member (16) and said core (12), said joining member having a different third permeability.

23. The trip device (40) of claim 22 wherein said first permeability is greater than said different third permeability and said different third permeability is greater than said different second permeability.



Prior Art

Fig.1



Prior Art

Fig.2

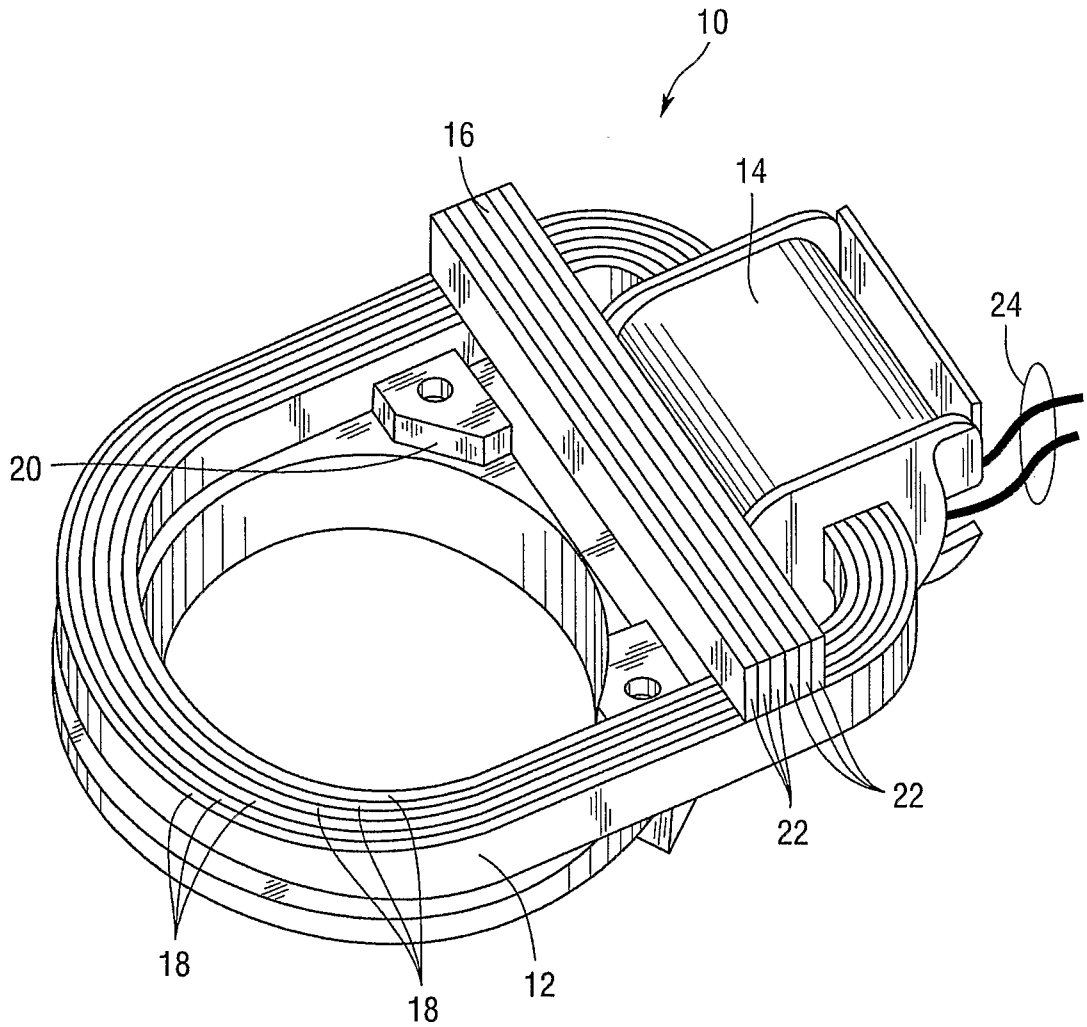


Fig.3

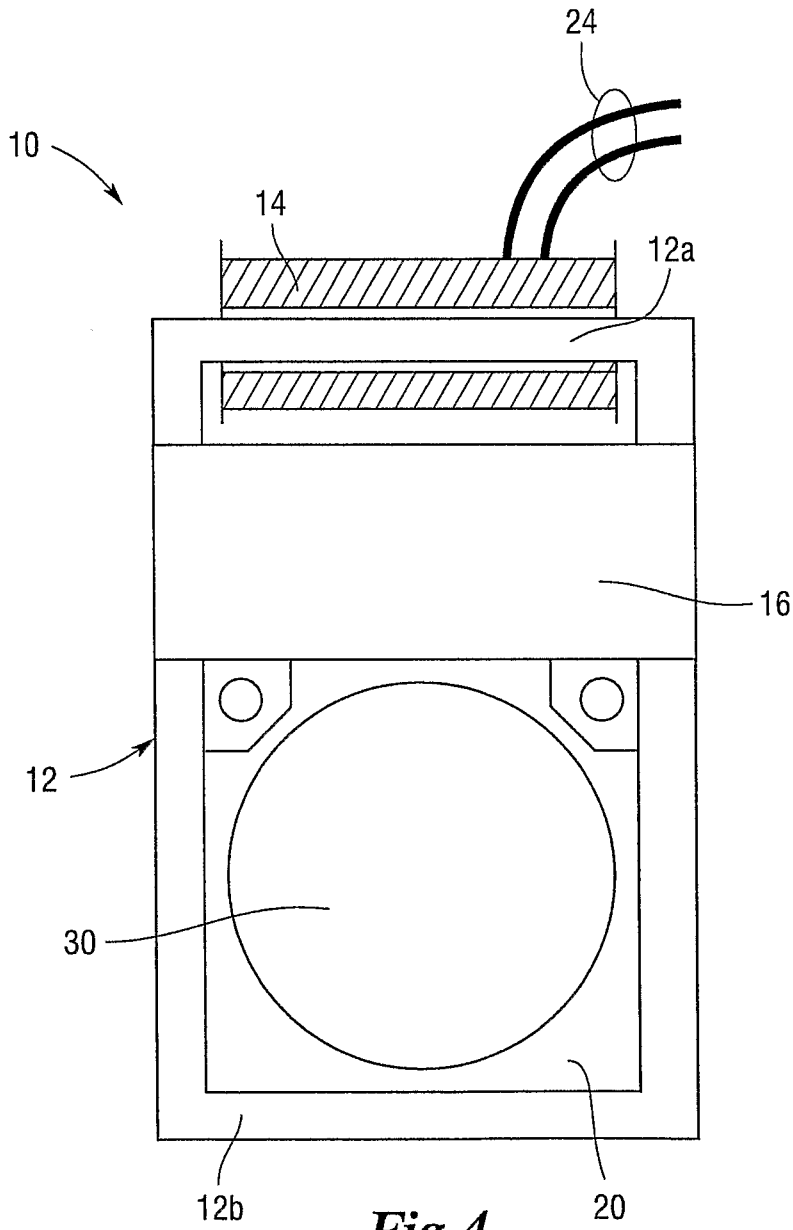
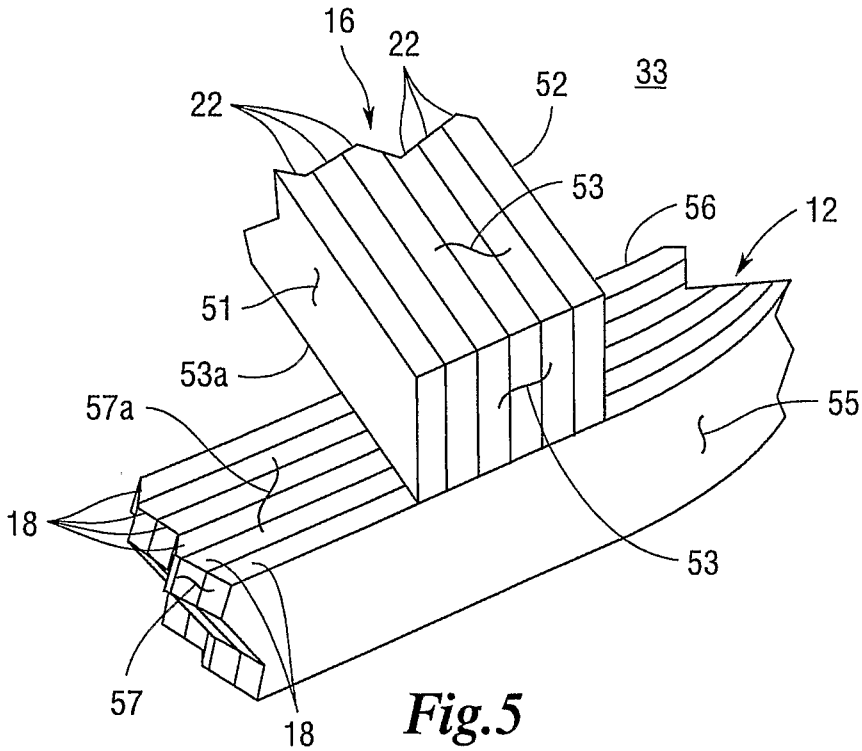


Fig.4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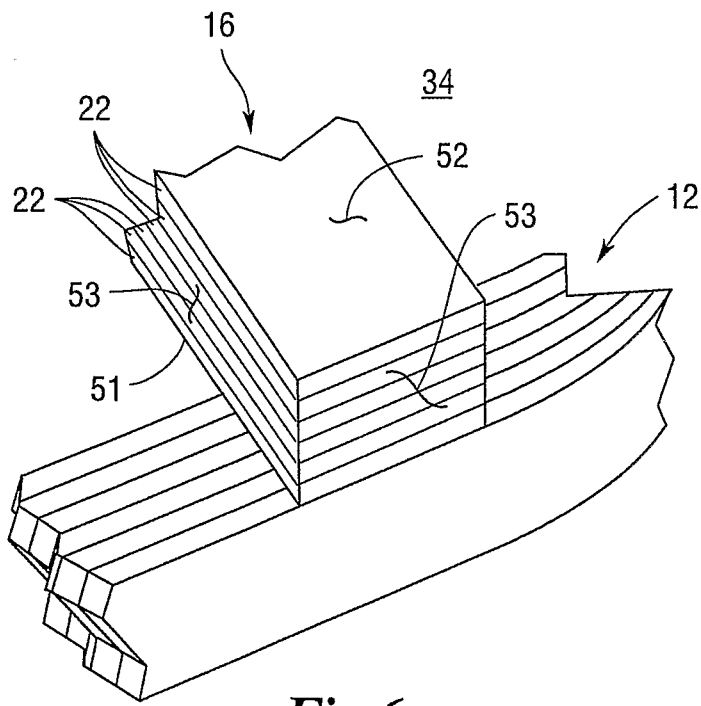
18

Fig.5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12
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51

Fig.6

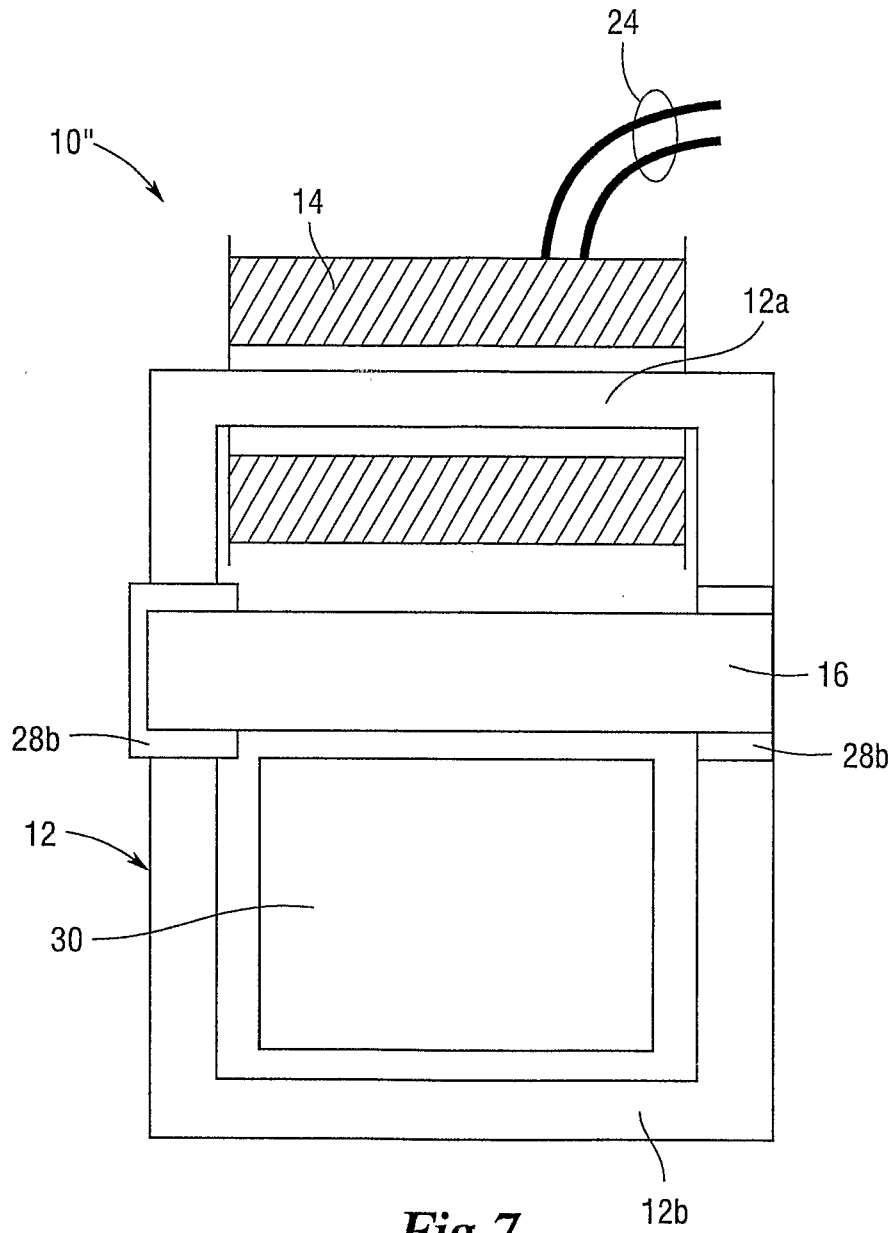

Fig. 7

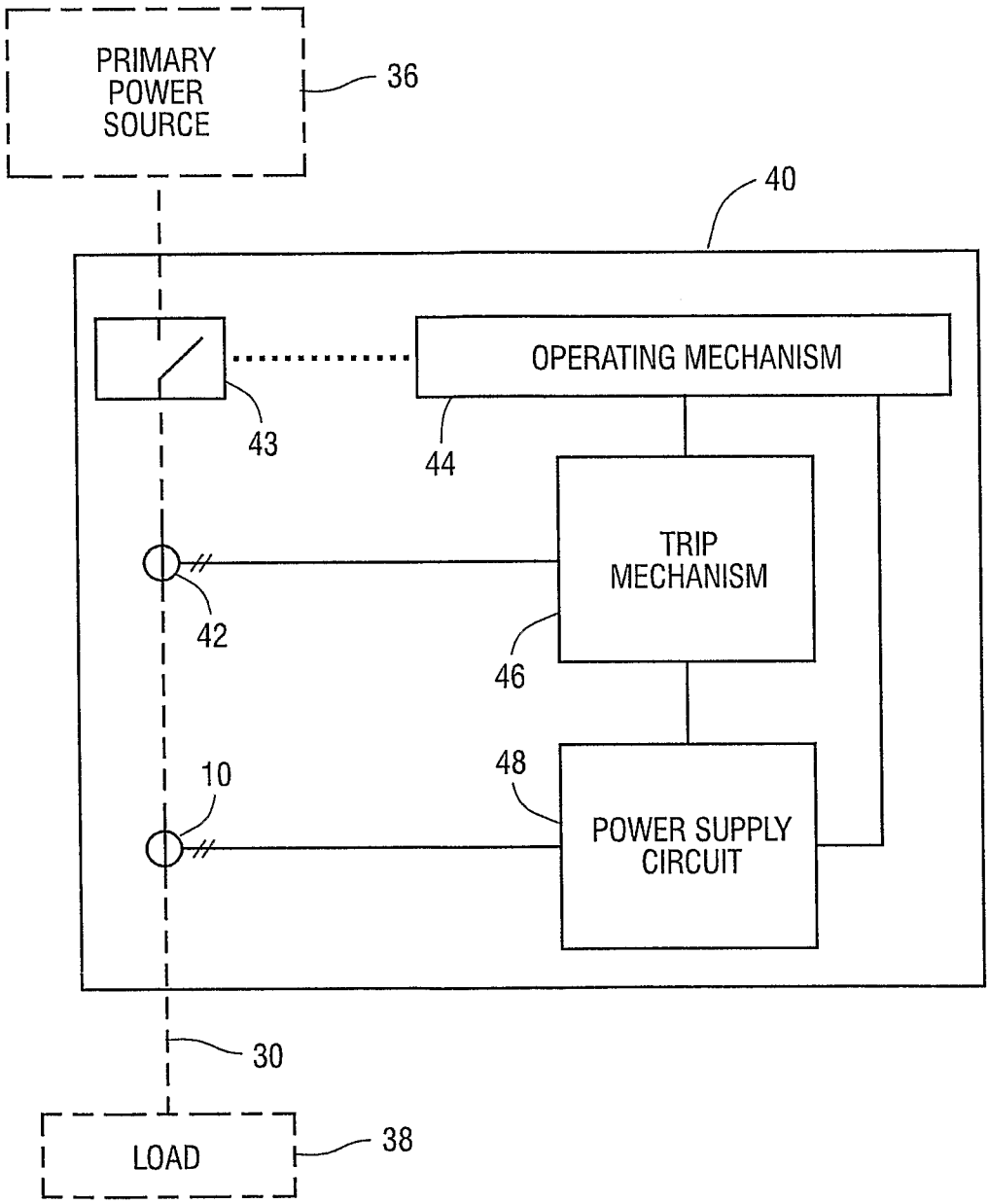
PRIMARY POWER SOURCE
36
40
OPERATING MECHANISM
43
44
TRIP MECHANISM
42
46
48
10
POWER SUPPLY CIRCUIT
30
LOAD
38

Fig.8

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/002944

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01F38/30 H01F3/12 H01H71/12

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)
H01F H01H

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.
X	EP 0 003 396 A (ICI PLC [GB]) 8 August 1979 (1979-08-08) claims 1,8 page 24, line 1 - line 18 figures 7,8	1-10, 12-15,17
A	US 5 726 846 A (HOUBRE PASCAL [FR]) 10 March 1998 (1998-03-10) claims 1,2,4,7,8,11 figures 1,9	1,2,4, 12,13,15
A	US 3 295 084 A (HORSTMAN CLIFFORD C) 27 December 1966 (1966-12-27) claims figures 1,4	1-3,6-8, 10, 12-14, 17-20,22

☐ 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

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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	Date of mailing of the international search report
14 February 2007	22/02/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Stichauer, Libor

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2006/002944

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-11

a known current transformer

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2. claims: 12-23

a trip device comprising a known current transformer

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2006/002944

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