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(54) Title: INTERLACED AMORPHOUS MATERIAL TRANSFORMER CORE

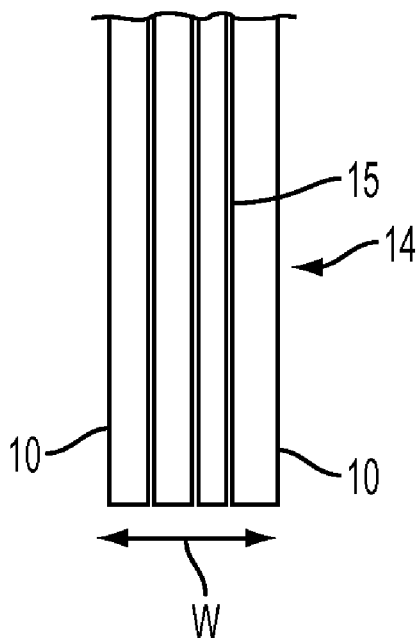


FIG. 4

(57) Abstract: A method of making a transformer core provides a plurality of amorphous material strips 10, 10'. The amorphous strips are wound to define a plurality of superposed layers 14, 14' of amorphous strips, each layer defining a core loop of the transformer. The winding step 1) provides at least a certain layer including interlaced, adjacent strips having differing widths thereby defining overall width of the certain layer to be greater than a width of the widest strip of the certain layer, and 2) ensures that a layer is in superposed relation with the certain layer.



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

— *as to the applicant's entitlement to claim the priority of
the earlier application (Rule 4.17(iii))*

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted
a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

INTERLACED AMORPHOUS MATERIAL TRANSFORMER CORE**[0001] BACKGROUND OF THE INVENTION**

[0002] The present invention relates to cores for an electric transformer and, more particularly to wound, interlaced amorphous material transformer cores.

[0003] Strips of amorphous materials are used to form conventional transformer cores because the material has low losses, and thus a higher efficiency. Amorphous material is mechanically fragile and very thin, and slitting and handling the material subsequently reduces the magnetic properties of the material, decreasing efficiency. The amorphous material is manufactured in limited widths. With reference to FIG. 1, the fragility of the material requires that strips 10 of amorphous steel material, arranged in groups 12, are wound in loops with quadrilateral cross-sections when forming a transformer core 17. Each layer wound adds to the height of the core loop and increases the cross-sectional area. As the power rating of a transformer increases, so must the cross-section of the core. Cores made of wound amorphous material with a quadrilateral cross-section result in a poor fill factor inside a transformer coil and, due to the limited production widths, multiple adjacent loops with quadrilateral cross-sections must be used to increase the total core cross-section as the power rating increases. It is difficult to keep multiple loops in place and avoid mechanical stress, which may damage the amorphous material.

[0004] Thus, there is a need to provide a transformer core whose overall cross-sectional width is formed by stacking several strips of amorphous material in interlaced layers, with some or each of the strips being offset or in overlapping relation.

[0005] SUMMARY OF THE INVENTION

[0006] An objective of the present invention is to fulfill the need referred to above. In accordance with the principles of the invention, this objective is obtained by providing a method of making a transformer core that provides a plurality of amorphous material strips. The amorphous strips are wound to define a plurality of superposed layers of amorphous strips, each layer defining a core loop of the transformer. The winding 1) provides at least a certain layer including interlaced, adjacent strips having differing widths thereby defining overall width of the certain layer to be greater than a width of the widest strip of the certain layer, and 2) ensures that a layer is in superposed relation with the certain layer.

[0007] In accordance with another aspect of an embodiment, a transformer core includes a certain layer of amorphous material strips. The certain layer is wound to define a core loop of the transformer. The certain layer includes adjacent, interlaced strips having differing widths thereby defining overall width of the certain layer to be greater than a width of the widest strip of the certain layer. At least another layer of amorphous material strips is superposed with the certain layer.

[0008] Other objectives, features and characteristics of the present invention, as well as the methods of operation and the functions of the related elements of the structure, the combination of parts and economics of manufacture will become more apparent upon consideration of the following detailed description and appended claims with reference to the accompanying drawings, all of which form a part of this specification.

[0009] BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention will be better understood from the following detailed description of the preferred embodiments thereof, taken in conjunction with the accompanying drawings, wherein like reference numerals refer to like parts, in which:

- [0011] FIG. 1 is side view of conventional groups of cut and stacked amorphous strips.
- [0012] FIG. 2 is a top view of the amorphous strips of FIG. 1.
- [0013] FIG. 3a is an end view of a layer of amorphous strips in adjacent, staggered positions in accordance with an embodiment.
- [0014] FIG. 3b is an end view of a layer of amorphous strips in unidirectional overlap positions in accordance with another embodiment.
- [0015] FIG. 3c is an end view of a layer of amorphous strips in poly-directional overlap positions in accordance with another embodiment.
- [0016] FIG. 4 is a top view of the strips of a layer of an embodiment, arranged in adjacent positions.
- [0017] FIG. 5 is an end view of a core showing stacked layers defining a height of the core.
- [0018] FIG. 6a is an end view of two layers of amorphous strips in a single layer overlap relation, with the next layer overlapping the previous layer in accordance with another embodiment.
- [0019] FIG. 6b is an end view showing symmetric poly-layer overlapping, with groups of layers overlapping each other in accordance with an embodiment.
- [0020] FIG. 6c is an end view showing asymmetrical poly-layer overlapping, with a unidirectional overlapping layer, overlapping another layer in accordance with an embodiment.
- [0021] FIG. 6d is an end view showing intermittent, single layer overlapping in accordance with an embodiment.

- [0022] FIG. 7 shows staggered amorphous strips for a transformer core having a non-quadrilateral shape in accordance with an embodiment.
- [0023] FIG. 8a shows a small offset of strips of layer with respect to the strips of a layer below in accordance with another embodiment.
- [0024] FIG. 8b shows a large offset of strips of a layer with respect to strips of a layer below in accordance with another embodiment.
- [0025] FIG. 8c shows staggered layers of strips with multiple layers of strips between overlap in accordance with another embodiment.
- [0026] FIG. 9a shows that a single layer can be wound at any angle.
- [0027] FIG. 9b shows that one or more layers can be wound at the same or different angles.
- [0028] FIG. 9c shows that multiple layers can be wound at any angle offset and with any amount of laminations.
- [0029] FIG. 10a shows a continuously wound core with distributed gap in accordance with an embodiment.
- [0030] FIG. 10b shows a continuous wound core in accordance with another embodiment.
- [0031] FIG. 10c shows a core formed by the combination of FIGs. 10a and 10b with a gap between continuous laminations.
- [0032] DETAILED DESCRIPTION OF AN EXAMPLE EMBODIMENT
- [0033] As used herein and by those skilled in the art, the term "strip" refers to a lamination of amorphous magnetic material of limited width that has been fully parted to create a certain length. The term "group" refers to a plurality of strips

that are assembled so as to be substantially aligned on both their longitudinal and transverse edges. The term "layer" refers to a single winding of a core loop that can comprise one or more strips.

[0034] In accordance with an embodiment, a method stacks of amorphous material (such as steel) strips in layers to increase the width of a core loop or to create a transformer core with a cross-section that deviates from a quadrilateral shape. With reference to layer end views in FIGs. 3a-3c, within a single layer 14 of a core loop, the amorphous material strips 10 may be wound in adjacent, interlaced positions (FIG. 3a) with gaps between lamination edges 15 forming the joints. Alternatively the strips 10 or laminations can be in overlapping, interlaced relation. FIG. 3b shows a unidirectional overlap of amorphous strips 10 with varied overlap lengths forming the joints, while FIG. 3c shows a poly-directional overlap of amorphous strips 10, with varied overlap lengths forming the joints. In FIGs. 3a-3c, the dimensions a, b, c, are defined as the width of a strip and dimensions d and e being a gap dimension or an overlap dimension. Thus, in FIGs. 3a-3c the dimensional relationships can be as follows: $a=or\neq b=or\neq c$, $d=or\neq e$, with the dimensions being selected to any suitable dimension. The thickness of each strip is about 0.0001 inches.

[0035] FIG. 4 shows a top view of strips 10 of a layer 14 with edges 15 thereof arranged in adjacent positions (as in FIG. 3a). Adjacent strips 10 of a layer 14 enable a cross-sectional width W (FIGs. 3a and 4) that is greater than the width of the widest strip (e.g., dimension a in FIG. 3a). Multiple strip widths may be used throughout the layer. FIG. 5 shows how multiple stacked layers 14 increases the height H of a core 17.

[0036] With reference to end views in FIGs. 6a-6d, layers of amorphous strips stacked in a superposed relationship can overlap a layer below. FIG. 6a shows single layer overlapping, with the next layer 14' (having unidirectional overlapping) overlapping the layer 14 (also having unidirectional overlapping). FIG. 6b shows symmetric poly-layer overlapping, with groups of layers overlapping each other. For example, group 18, comprising symmetrical amorphous strips 10', overlaps group 16, comprising symmetrical amorphous

strips 10. FIG. 6c shows asymmetrical poly-layer overlapping, with unidirectional overlapping layer 14' overlapping the layer 14. FIG. 6d shows intermittent single layer overlapping.

[0037] For larger core sizes associated with higher rating transformers, conventionally, wider steel laminations or strips are used. When the width of the steel is restricted due to manufacturing limitations, multiple amorphous steel core loops are typically used. The embodiment uses interlaced laminations or strips to increase the width of the core loop. Interlaced laminations are distinct from increasing the core width with merely adjacent loops because the interlaced laminations reinforce each other and no barrier is placed between interlaced laminations.

[0038] With reference to end views of layers in FIGs. 8a-6c and FIG. 7, the position of a strip in the next layer may be offset from the layer below. FIG. 7 shows staggered amorphous strips 10, 10' in layers (e.g., 14, 14') stacked in a superposed and interlaced relationship defining a transformer core, generally indicated at 17, having a non-quadrilateral shape. The overall cross-sectional width thus varies between layers as indicated by W_1 and W_2 , allowing the core 17 cross-section to have the non-quadrilateral shape. Non-quadrilateral shapes can have a better fill factor, improving the material efficiency in the transformer coil. The embodiment is an improvement over conventional methods, since it is difficult to cut non-quadrilateral shapes with amorphous steel because the material is delicate. Lamination interlacing as in the embodiment allows amorphous steel to be used for core loops that are not quadrilateral or parallelograms.

[0039] FIG. 8a shows a small offset of strips 10' of layer 14' with respect to the strips 10 of layer 14. FIG. 8b shows a large offset of strips 10' with respect to strips 10 there-below. FIG. 8c shows staggered layers 14, 14' with multiple layers between overlap. Offset amorphous material strips 10, 10' may be wound in every layer or with any numerical arrangement of layers between the next offset. If the amorphous material strips overlap within a layer, then the strips may or may not be offset between the layers. If strips are wound to overlap

within a layer, the strips may be offset to not overlap for any number of layers before the next overlap. Between all and none of the strips may overlap within a layer. Any number of layers may also overlap any number of layers. The gap between adjacent lamination strips or the overlap distance may vary between and within core loops.

[0040] Conventional transformer joints often have offsets between core loop layers, and a parallelogram core loop may also have offset core layers, but these offsets follow a pattern of an offset distance between two layers. An interlaced lamination offset of the embodiments can occur with any pattern, and a lamination in one layer may overlap multiple laminations in a single layer. Essentially, adjacent lamination interfaces are offset between layers.

[0041] For clarity of illustration, FIGs. 3a-8c show gaps between layers (e.g., 14, 14'). It can be appreciated that the layers 14, 14' and all further layers are stacked in superposed relationship with no significant gap between layers.

[0042] With reference to FIG. 9a, a single layer 14 can be wound at any angle. FIG. 9b shows that one or more layers can be wound at the same or different angles to increase cross-sectional area or approximate a cross-sectional shape (e.g., rectangle). FIG. 9c shows that multiple layers can be used at any angle offset and with any amount of laminations 10 to approximate cross-sectional shapes (e.g., non-quadrilateral shapes). Thus, laminations within a layer may be wound at an angle to overlap adjacent laminations within the same layer. Subsequent layers may be wound at the same angle or at a different angle from the previous layer.

[0043] With reference to FIG. 10a, a continuously wound core 17 is shown with a distributed gap 20 in accordance with an embodiment. Alternatively, FIG. 10b shows a continuous wound core 17'. Still further, FIG. 10c shows a core 17" formed by the combination of FIGs. 10a and 10b with a gap between continuous laminations. Winding of the cores 17 is conventional and may employ an arbor of the type disclosed U.S. Patent No. 5,315,754, the contents of which is hereby incorporated by reference into this specification.

- [0044] The process disclosed herein may be used for core loops in single or multiple phase transformers. One or more loops with identical or different cross-sections may pass through a transformer coil. This technique may be used to produce quadrilateral core loop cross-sections as well as other cross-sectional shapes.
- [0045] The mechanical stability of the amorphous material core is greater with interlaced or offset strips than if larger widths are achieved using adjacent but separate loops. This allows larger cores to be manufactured to meet the requirements of higher transformer power ratings.
- [0046] It can be appreciated that the embodiments increase the overall width of the transformer core or core loop cross-section by using multiple strips of limited widths. This allows for many different strip widths to be imitated without requiring manufacturing large strip widths or additional slitting of standard manufactured widths. Increasing cross-sectional widths allow production of higher transformer power ratings. The embodiments also allow the overall width of the transformer core or core loop to vary between layers, permitting any cross-sectional shape, which can increase the filling factor within a transformer coil, thus increasing the material efficiency of the unit. By staggering strip position within layers and overlapping intra- and/or inter-layer strips, a laminar contact area is provided that becomes a site for compression. This compression between laminations improves the mechanical stability of the core or core loop without adding mechanical stresses from additional fixtures to hold the separate segments.
- [0047] The foregoing preferred embodiments have been shown and described for the purposes of illustrating the structural and functional principles of the present invention, as well as illustrating the methods of employing the preferred embodiments and are subject to change without departing from such principles. Therefore, this invention includes all modifications encompassed within the spirit of the following claims.

What is claimed is:

1. A method of making a transformer core comprising the steps of:
providing a plurality of amorphous material strips, and
winding the amorphous strips to define a plurality of superposed layers of amorphous strips, each layer defining a core loop of the transformer, the winding step 1) providing at least a certain layer including interlaced, adjacent strips having differing widths thereby defining overall width of the certain layer to be greater than a width of the widest strip of the certain layer, and 2) ensuring that a layer is in superposed relation with the certain layer.
2. The method of claim 1, wherein the layer superposed with the certain layer includes adjacent, interlaced strips having differing widths so that an overall width thereof is greater than a width of the widest strip thereof.
3. The method of claim 1, wherein the winding step further includes winding the superposed layers of strips so that an overall cross-sectional width varies between layers thereby defining the core having a non-quadrilateral cross-sectional shape.
4. The method of claim 1, wherein winding of the certain layer includes overlapping certain of adjacent strips of the certain layer.
5. The method of claim 4, wherein the overlapping is unidirectional.
6. The method of claim 4, wherein the overlapping is poly-directional.
7. The method of claim 2, wherein edges of certain adjacent strips of the certain layer or the layer superposed therewith are disposed in spaced relation defining a gap there-between.
8. The method of claim 7, wherein a distance of the gap varies within a layer.

9. The method of claim 1, wherein the strips of the layer superposed with the certain layer are offset with respect to strips of the certain layer.
10. The method of claim 1, wherein the winding step is continuous until completion thereof.
11. The method of claim 1, wherein the winding step provides at least one gap in the winding.
12. A transformer core comprising:
 - a certain layer of amorphous material strips, the certain layer being wound to define a core loop of the transformer, with the certain layer including adjacent, interlaced strips having differing widths thereby defining overall width of the certain layer to be greater than a width of the widest strip of the certain layer, and
 - at least another layer of amorphous material strips superposed with the certain layer.
13. The transformer of claim 12, wherein the another layer includes adjacent, interlaced strips having differing widths so that an overall width thereof is greater than a width of the widest strip thereof.
14. The transformer of claim 12, wherein an overall cross-sectional width varies between layers thereby defining the core having a non-quadrilateral cross-sectional shape.
15. The transformer of claim 12, wherein strips within the certain layer or strips within the another layer are in overlapping relationship.
16. The transformer of claim 12, wherein strips within the certain layer and strips within the another layer are in overlapping relation.
17. The transformer of claim 15, wherein the overlapping is unidirectional or poly-directional.

18. The transformer of claim 13, wherein edges of certain adjacent strips of the certain layer or edges of certain adjacent strips of the another layer are disposed in spaced relation defining a gap there-between.
19. The transformer of claim 17, wherein a distance of the gap varies within a layer.
20. The transformer of claim 12, wherein the strips of the another layer are offset with respect to strips of the certain layer.

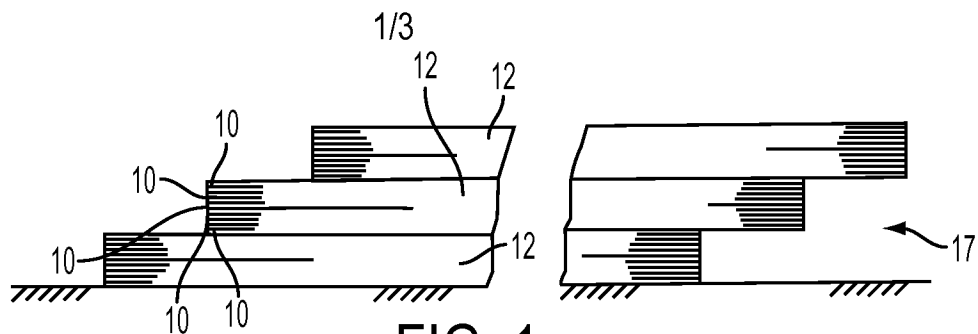


FIG. 1
PRIOR ART

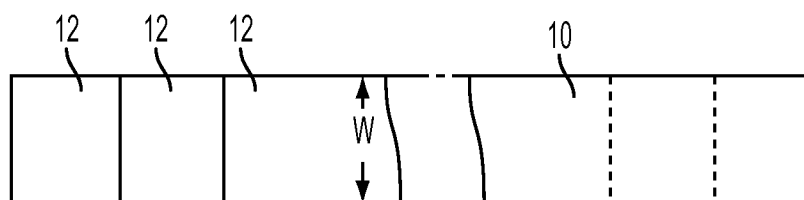


FIG. 2
PRIOR ART

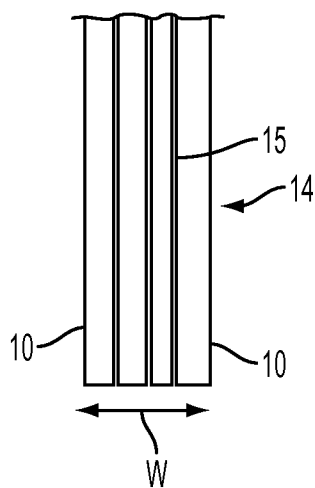


FIG. 4

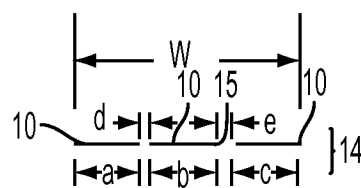


FIG. 3a

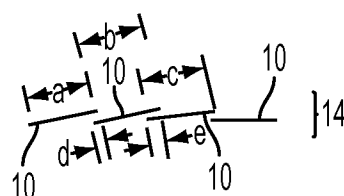


FIG. 3b

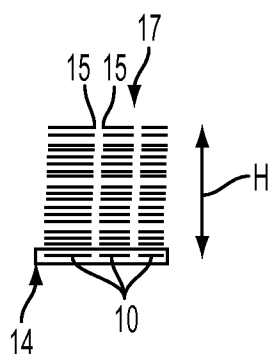


FIG. 5

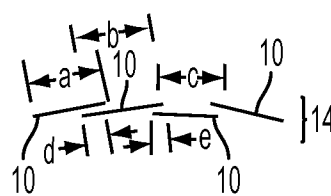


FIG. 3c

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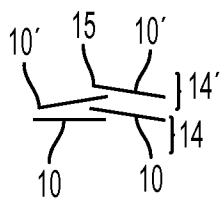


FIG. 6a

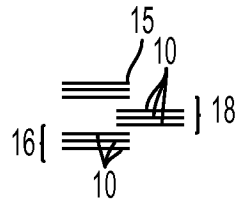


FIG. 6b

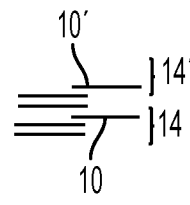


FIG. 6c

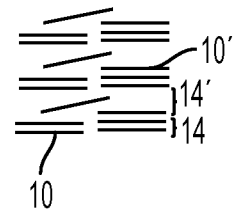


FIG. 6d

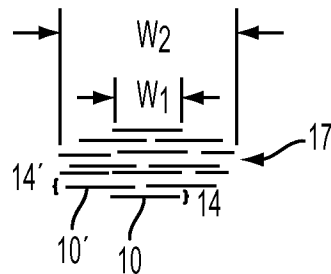


FIG. 7

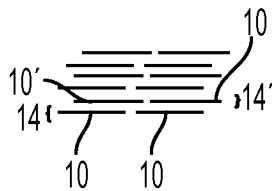


FIG. 8a

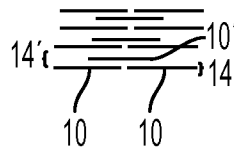


FIG. 8b

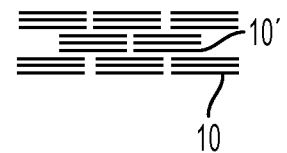


FIG. 8c

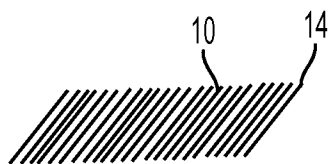


FIG. 9a

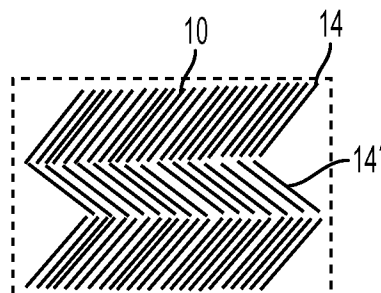


FIG. 9b

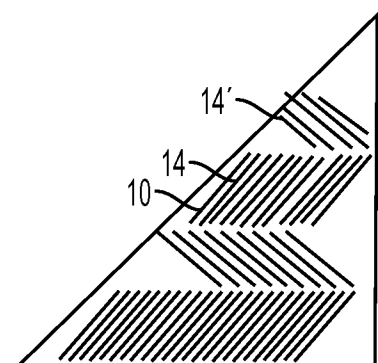


FIG. 9c

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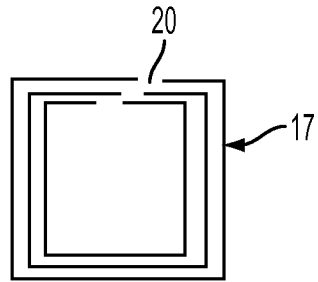


FIG. 10a

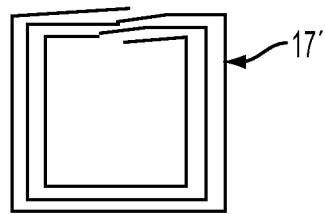


FIG. 10b

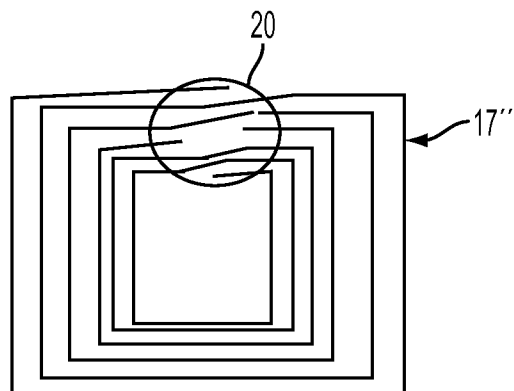


FIG. 10c

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/037405

A. CLASSIFICATION OF SUBJECT MATTER INV. H01F27/25 H01F41/02 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) H01F		
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, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 399 365 A (SUBOVICI VADIM) 27 August 1968 (1968-08-27) abstract column 1, line 33 - column 2, line 61; claims 1-3; figures 1,3 -----	1-20
A	JP 11 195547 A (IWATA ELECTRIC WORKS) 21 July 1999 (1999-07-21) abstract -----	1-20
A	US 2 579 560 A (FORD JAMES G) 25 December 1951 (1951-12-25) abstract -----	1-20
A	GB 410 230 A (WENDOLYN FREDOLYN GAKLE) 17 May 1934 (1934-05-17) abstract -----	1-20
☐ 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 application or patent 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	
13 August 2012	22/08/2012	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Warneck, Nicolas	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2012/037405

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3399365	A	27-08-1968	BE 671502 A 14-02-1966
			US 3398450 A 27-08-1968
			US 3399365 A 27-08-1968
JP 11195547	A	21-07-1999	NONE
US 2579560	A	25-12-1951	NONE
GB 410230	A	17-05-1934	NONE