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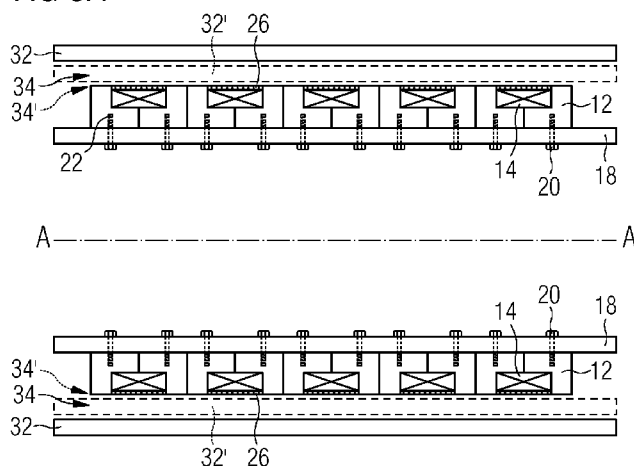
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ER SURFACES TO AN OUTER MECHANICAL SUPPORT STRUCTURE

FIG 3A



(57) Abstract: The invention provides a cylindrical electromagnet comprising annular coils attached by their radially outer surfaces to an outer mechanical support structure. This is manufactured by a method comprising the steps of providing a demountable mandrel with circumferential slots; winding wire into the circumferential slots to form coils; providing a mechanical support structure over a radially outer surface of the coils, with a first clearance dimension between the outer surface of the coils and a radially inner surface of the mechanical support structure; deforming the mechanical support structure so as to reduce its internal diameter and reduce the first clearance dimension to a second clearance dimension which is less than the first clearance dimension; applying a hardening material to the resultant structure; causing or allowing the hardening material to harden, thereby bonding the coils to the mechanical support structure and removing the demountable mandrel.



CYLINDRICAL ELECTROMAGNET COMPRISING ANNULAR COILS
ATTACHED BY THEIR RADIALY OUTER SURFACES
TO AN OUTER MECHANICAL SUPPORT STRUCTURE

5 The present invention relates to the construction of cylindrical electromagnets comprising annular coils attached by their radially outer surfaces to an outer mechanical support, and methods for making such electromagnets. The present invention is particularly applicable to superconducting magnets for use in MRI imaging equipment, but is not restricted to such applications and may be applied to
10 the manufacture of both superconducting and resistive electromagnets.

Conventionally, such cylindrical electromagnets have been constructed by winding wire into annular channels formed in a radially outer surface of a former, being a cylinder typically of aluminium or a composite material.

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More recently, and as illustrated in Figs. 1A and 1B, there have been developed cylindrical magnets in which wire is wound into re-useable journals 12, to form coils 14 and where a mechanical support structure 16, typically a tube of a composite non-magnetic material such as glass-reinforced-plastic (GRP), is then slid over the
20 journals 12 and the coils 14, and the whole assembly impregnated with a hardening material such as an epoxy resin. The journals 12 are coated in a release material, which prevents them from becoming bonded to the coils by the hardening material. Once the hardening material has cured, the re-useable journals 12 are removed from the coils 14, and there remains a magnet structure comprising impregnated coils 14
25 bonded by their radially outer surface, which is commonly known as the A2 surface, to an outer mechanical support structure 16.

In Fig. 1A, and several of the appended drawings, the illustrated structure is essentially rotationally symmetrical about the illustrated axis A-A. References to
30 “axial” directions refer to directions parallel to axis A-A, and references to “radial” directions perpendicular to axial directions.

Fig. 1B shows a partially disassembled structure of retaining tube 18 and journal 12 segments. As shown, to facilitate disassembly, the ends 21 of each journal segment

need to be carefully angled with respect to the surface of the retaining tube 18, as will be explained below.

In preparation for winding, the journal segments are attached in their respective
5 positions by mechanical retaining means 20. In the example of Fig. 1A, these mechanical retaining means are bolts, passing from the interior of the retaining tube 18, through the material of the retaining tube into threaded blind holes 22 in the journal 12 segments. Preferably, some type of sealant, for example modelling clay, is used to prevent the hardening material such as epoxy resin from entering the blind
10 hole 22. With the journal 12 segments in place, wire is wound into the journals 12 to form the coils 14. Once this stage is completed, the outer mechanical support structure 16, such as a GRP tube, is slid over the coils. This should be dimensioned so as to have only a small clearance 24 between the radially outer surfaces of the coils 14 and the journal segments 12 and the radially inner surface of the outer
15 mechanical support structure 16. An interface layer 26, such as glass fibre cloth, may be provided over the radially outer surfaces of the coils. This will protect the coils during positioning of the tubular mechanical support structure 16 and reinforce the bond between coil 14 and tubular mechanical support structure 16 once formed.

20 The resultant structure is then impregnated with a hardening material such as an epoxy resin, in the conventional manner. Once the hardening material has cured, the journal 12 segments are released from the retaining tube 18, for example by removing bolts 20. The retaining tube 18 is then slid from the centre of the structure, and the journal 12 segments are removed from the coils. It is at this stage that the
25 angled ends 21 of the journal 12 segments are important in allowing one or more journal segments to be removed with the others in place.

Once all journal segments have been removed, the structure 14 of Fig. 2 remains: an outer tubular mechanical support structure 16 with annular coils 14 bonded to an
30 inner surface thereof. This structure forms the basis of the electromagnet.

Figs. 1C and 1D show an alternative arrangement. Here, the journal segments 30 comprise only wall parts positioned between coil-winding cavities. In Figs. 1A and 1B, the journal 12 segments comprise also radially inner surfaces 28 of the coil-

winding cavities. Accordingly, in the arrangement of Figs. 1C and 1D, the retaining tube 18 has an outer diameter corresponding to the inner diameter of the coils 14.

The retaining tube 18, the surfaces of journal segments 30 and the mechanical retaining means such as bolts 20 should all be coated with a release material which prevents the hardening material from bonding to those surfaces.

Something of a difficulty arises in such methods due to the clearance 24 which must be provided between the radially inner surface of the tubular mechanical support structure 16 and the radially outer surfaces of the coils 14 and the journals 12, 30.

For reasons of bond strength, the bond 31 between coils 14 and mechanical support structure 16 should be of minimum thickness and/or filled with reinforcement such as glass fibre cloth 26 or glass beads. The requirement for thin bond 31 conflicts with the need for large clearances 24 to enable the mechanical support structure 16 to be readily slid over, and centralised relative to, the coils 14 to efficiently produce and align the assembly ready for impregnation. As the mechanical support structure is slid over the coils and any reinforcement, there is a risk of damage to coil windings and potential for parts of the reinforcement to be displaced, such as by being scraped off by the mechanical support structure during assembly.

The present invention addresses these difficulties by providing a deformable tubular mechanical support structure of internal diameter having a relatively large clearance when slid over the coils and journals, but which is mechanically deformed so as to reduce its internal diameter into contact or closer proximity to the outer surfaces of the coils and the journals.

In particular, the present invention provides apparatus and methods as defined in the appended claims.

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The above, and further, objects characteristics and advantages of the present invention will become more apparent from the following description of certain embodiments thereof, along with the accompanying drawings, wherein:

Figs. 1A-1B shows an example of an A2 bonded magnet at a certain step within a conventional method of manufacture;

Figs. 1C-1D shows an example of an A2 bonded magnet at a certain step within a variant of this conventional method of manufacture;

5 Fig. 2 shows an axial cross-section of an A2 bonded magnet which may be produced by the methods discussed with reference to Figs. 1A-1D;

Fig. 3A shows an example of the present invention applied to a structure such as shown in Fig. 1A;

Fig. 3B shows an example of the present invention applied to a structure such as
10 shown in Fig. 1B;

Fig. 4A shows an expanded grid, as may be used in an embodiment of the present invention;

Fig. 4B shows a tubular mechanical support structure formed of an expanded grid as shown in Fig. 4A;

15 Fig. 5A shows an expanded grid, as may be used in an embodiment of the present invention;

Fig. 5B shows a tubular mechanical support structure formed of an expanded grid as shown in Fig. 5A;

Fig. 6 generally represents embodiments of the present invention in which a
20 mechanical support structure is twisted;

Fig. 7 shows a tubular mechanical support structure being an example of the general case shown in Fig. 6;

Fig. 7A shows a partial view of tooling which may be employed with a mechanical support structure such as shown in Fig. 7;

25 Fig. 8 tubular mechanical support structure formed of an expanded grid as shown in Fig. 9; and

Fig. 9 shows an expanded grid, as may be used in an embodiment of the present invention

30 According to the method of the present invention, as schematically illustrated in Fig. 3A, a deformable tubular mechanical support structure 32 is provided, having an internal diameter having a relatively large clearance 34 when slid over the coils 14 and journals 12. After the coils 14 have been wound, the deformable tubular mechanical support structure 32 is slid over the coils 14 and the journals 12. Being
35 of relatively large internal diameter, with large clearance 34 over the outer surfaces of

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the coils 14 and journals 12, this is relatively easy. Interface layers 26 of a filler material such as glass fibre cloth or a paste of glass beads in uncured resin, are illustrated, positioned between the coils 14 and the support structure 32. Their presence is optional, but preferred. As shown in Fig. 3A, such interface layers 26 may be wound individually over each coil, into the coil journal. Alternatively, as illustrated in Fig. 3B, the coils may fill the coil journals, and the filler layer may be wound over the entire cylindrical length of coils and journal surfaces.

Once in position, the deformable tubular mechanical support structure 32 is mechanically deformed so as to reduce its internal diameter into contact or closer proximity to the outer surfaces of the coils 14 and the journals 12, moving to position 32' in Fig. 3A. Preferably, the deformed tubular mechanical support structure 32' has an internal diameter with a smaller clearance 34' over the outer surfaces of the coils 14 and journals 12 than is practical in the more conventional arrangements of Figs. 1A-1D. In some arrangements, the clearance 34' may be zero.

In presently preferred embodiments, the deformable tubular mechanical support structure 32 has an inner diameter 10-50mm larger than the outer diameter of the coils and the journals. Such a large clearance 34 makes it relatively easy to assemble without danger of damage or disruption to the wound coils.

Once in position, the tubular mechanical support structure 32 is deformed to have a smaller diameter. Preferably, the final diameter of the deformed tubular mechanical support structure 32' is 0-5mm greater than the outer diameter of the coils 14 and the journals 12.

While Fig. 3A shows an example of the present invention applied to a coil and journal structure similar to that shown in Fig. 1A, Fig. 3B shows a similar example of the present invention applied to a coil and journal structure similar to that shown in Fig. 1B.

According to different embodiments of the invention, the required deformation may be performed mechanically, by applying appropriate forces directly to the deformable tubular mechanical support structure 32; or may be performed electromagnetically, by causing currents to flow in the deformable tubular mechanical support structure 32

when inside a strong magnetic field, which will induce forces upon the deformable tubular mechanical support structure 32 and cause its deformation.

More simple to produce and use are those deformable tubular mechanical support
5 structures and methods employing simple mechanical deformation. In a particularly low-cost embodiment, a perforated and expanded metal grid such as that shown at 40 in Fig. 4A may be rolled into a tube 41 and used as the deformable tubular mechanical support structure 32. The required deformation may be provided by simply squeezing the tube by applying circumferentially compressive forces using
10 ratcheting cargo straps 42 or similar tensioning means, tightened at intervals around the outer surface of the deformable tubular mechanical support structure 32, for example as shown in Fig. 4B.

Alternatively, mechanical links such as hooks 44 may be applied as shown in Fig. 4A
15 to the grid at locations such as shown at ends of the tube 41 or clamps such as hydraulic or mechanical grips 46 at locations such as shown at 48 in Fig. 4A at ends of the tube 41. These mechanical links may then be pulled in opposite directions, away from an axial mid-point of the tube 41. This will cause a contraction of the deformable tubular mechanical support structure 32 in the radial direction, as it
20 lengthens in the axial direction.

In some embodiments, a specially produced perforated expanded metal grid may be used. By providing only certain regions which are perforated, the tension applied may be varied over the surface of the coils and journals. For example, the expanded

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metal grid 50 partially illustrated in Fig. 5A may be used to produce a deformable tubular mechanical support structure 52 as shown in Fig. 5B.

The expanded metal grid 50 may be produced by laser or water jet cutting of a sheet of aluminium or other non-magnetic material; or by stamping. It may be produced as shown, or slots may be cut and the sheet of material stretched into the expanded arrangement shown.

Fig. 5B shows the deformable tubular mechanical support structure 52 in its state after being slid over the coils and journals. The coils, journals, support tube and so on are not shown in this drawing for clarity of illustration of the support structure 52. By applying differential compressive load forces 54 to the expanded metal grid, for example as illustrated in the drawing, the perforations in the grid will close by a certain extent illustrated at 56 and the mechanical support structure 52 will reduce in diameter as illustrated at 58. In this embodiment, axially-directed solid bars 60 are joined by struts 62 separated by angled perforations 64. By applying opposing axial forces 54 to adjacent solid bars 60, the mechanical support structure 52 may be deformed so as to radially expand or contract away from its nominal dimensions 66. In the present invention, the mechanical support structure is required to contract towards the radially outer surface of the coils. Application of the opposing forces according to arrows 54 in Fig. 5B will cause the mechanical support structure to contract to reduced diameter as shown by arrows 58.

In some arrangements, it may be found sufficient to provide the angled perforations 64 at only three or four positions around the circumference of the support structure 52.

As illustrated in Fig. 5B, alternate axial bars 60 may be created so as to respectively extend beyond, or fall short of, a the nominal end plane 67 of the tube. Each axial bar which extends beyond the nominal end plane 60 at one end will fall short of the nominal end plane at the other end by a similar amount. By careful selection of dimensions, once the tube 52 has contracted by the required amount, due to application of opposing axial forces 54, the ends of all axial bars should lie at least approximately on the nominal end planes 67.

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In further embodiments, a deformable tubular mechanical support structure comprising essentially axial strips linked together in some flexible manner may be twisted such that one end of the structure is rotated relative to the other, and a contraction in the diameter of the structure results.

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Fig. 6 illustrates the general concept of such embodiments. Axial strips 70 of material are held together by flexible joints 82, to form a mechanical support structure 78 of generally cylindrical shape 66.

10 As illustrated in Fig. 7, by twisting 74 a first end of the mechanical support structure 78 relative to the other end, as illustrated, the flexible joints 82 allow the axial strips 70 to move relative to one another, and the cylinder contracts in the diametric dimension. In the illustrated arrangement, the ends of the mechanical support structure 72 are constrained to remain at a constant diameter, and a concave outer
15 surface 76 of the mechanical support structure 72 results. Note that the illustrated surface 76 is only a notionally continuous surface. In reality, the surface will be made up of strips 70, flexible joints and spaces between them.

In a variant of this embodiment, no flexible joints 82 are provided, but the support
20 structure is made up of separate axial strips 70 held in respective relative locations by retaining arrangements near respective ends of the strips 70.

In preferred embodiments, however, the ends of the mechanical support structure 72 are not constrained to remain at a constant diameter and the outer surface 76 of the
25 mechanical support structure 72 remains cylindrical. Optionally, the support structure 78 may be formed longer than the required final magnet, and deformed end-pieces may be cut off after the magnet structure is completed.

Fig. 7A shows a part axial view of a tooling arrangement which may be used to cause
30 diametric contraction of the mechanical support structure 78 of Fig. 6. A rotary ring 102, only partially illustrated in Fig. 7A, is provided with slots 106 at intervals around its circumference, for receiving respective ends of axial strips 70 at one axial end of the mechanical support structure 78. A similar static ring, not illustrated, may be provided at the other axial end of the mechanical support structure 78 to retain the
35 other ends of the axial strips 70 in a fixed position. Slots 106 retain the ends of the

axial strips in the circumferential direction, but allow movement in the axial direction. Adjacent each slot 106 is provided a tapered anvil 104. The ends of the axial strips protrude from the rotary ring in the direction of the tapered anvils 104. This may be achieved by providing the tapered anvils to the side of the rotary ring closest to the
5 axial mid-point of the mechanical support structure 78. The rotary ring 102 is then rotated, in the direction 108 shown. The rotary ring 102 carries the ends of the axial strips with it into contact with the tapered surfaces of the anvils 104. The rotary ring rotates further, driving the ends of the axial strips over the surfaces of the tapered anvils 104, forcing them radially inwards, a relative motion which is permitted by the
10 shape of the slots 106. This action assists in reducing the diameter of the mechanical support structure 78 in a controlled manner, and may be easier to achieve than a simple twist of the mechanical support structure 78 without using the anvils 104.

15 A mechanical support structure 90 as shown in Fig. 8 may be produce using the step of applying an opposite twist to increase the diameter of the mechanical support structure 78. This structure may be constructed from a perforated sheet 92 of material such as aluminium, as represented in Fig. 9. The sheet has slots 94 cut through it, to define spacers 96 attached to respective axial bars 98 at respective ends of each
20 spacer. The sheet 92 may be expanded by pulling in directions perpendicular to the axial bars and a structure similar to that shown in Fig. 5A will result. Alternatively, the sheet 92 may be formed into a tube having an interior diameter rather less than the outer diameter of the coils 14. By twisting that tube in such a direction as to place the spacers 96 under tension, the tube is made to increase in diameter, the axial bars
25 become twisted and the expanded tube 90 shown in Fig. 8 results. The expanded tube may then be slid over the coils 14 and an opposite twist may be applied, to reduce the internal diameter of the tube onto the coils.

While the present invention has been described with reference to a limited number of
30 specific embodiments, given by way of example only, numerous modifications and variations will be apparent to those skilled in the art. For example, while the above description refers to sliding the mechanical support structure into place over the coils, the invention may alternatively be practised by forming a tubular mechanical support structure by wrapping a sheet of appropriately formed material around the coils and
35 forming it into a tube in-situ. While the mechanical support structure of various

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embodiments has been described as being of a metal, it may be formed of any other material, such as a plastic or composite material, provided that such material provides the required properties of being non-magnetic, resilient and deformable.

The present invention encompasses such modifications and variations within the
5 scope of the appended claims.

CLAIMS

1. A method for manufacturing a cylindrical electromagnet comprising annular coils attached by their radially outer surfaces to an outer mechanical support
5 structure, comprising the steps of:
 - providing a demountable mandrel with circumferential slots;
 - winding wire into the circumferential slots to form coils;
 - providing a mechanical support structure over a radially outer surface of the coils,
with a first clearance dimension between the outer surface of the coils and a radially
10 inner surface of the mechanical support structure;
 - mechanically deforming the mechanical support structure so as to reduce its
internal diameter and reduce the first clearance dimension to a second clearance
dimension which is less than the first clearance dimension;
 - applying a hardening material to the resultant structure;
 - 15 - causing or allowing the hardening material to harden, thereby bonding the coils to
the mechanical support structure and
 - removing the demountable mandrel.
2. A method according to claim 1 wherein the step of deforming the mechanical
20 support structure so as to reduce its internal diameter comprises applying opposing
axially directed forces to the mechanical support structure.
3. A method according to claim 1 wherein the step of deforming the mechanical
support structure so as to reduce its internal diameter comprises twisting the
25 mechanical support structure.
4. A method according to claim 1 wherein the step of deforming the mechanical
support structure so as to reduce its internal diameter comprises applying
circumferentially compressive forces to the mechanical support structure.
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5. A method according to claim 1 wherein the step of deforming the mechanical
support structure so as to reduce its internal diameter comprises applying
electromagnetic pulses to the mechanical support structure.

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6. A method according to claim 1 wherein the step of providing a mechanical support structure over a radially outer surface of the coils comprises forming a tubular mechanical support structure and sliding it over the radially outer surface of the coils.

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7. A method according to claim 1 wherein the step of providing a mechanical support structure over a radially outer surface of the coils comprises wrapping a sheet of suitable formed material around the radially outer surface of the coils.

10 8. A method according to any preceding claim, wherein the mechanical support structure comprises a tube of perforated material.

9. A method according to claim 8 wherein the mechanical support structure comprises a number of axially-directed bars joined in the circumferential direction by
15 flexible links to form a tube of perforated material.

10. A method according to claim 8 or claim 9 wherein the tube of perforated material is formed by cutting slots in a sheet of the material and applying a force to the slotted material to cause the material to expand and the slots to open into
20 perforations, then forming the sheet of material into a tube.

11. A method according to claim 8 or claim 9 wherein the tube of perforated material is formed by cutting slots in a sheet of the material, then forming the sheet of material into a tube, and applying a force to the slotted material to cause the material
25 to expand and the slots to open into perforations.

12. A method according to claim 10 wherein the force is applied by twisting the tube.

30 13. A cylindrical electromagnet comprising annular coils attached by their radially outer surfaces to an outer mechanical support structure as may be produced by the method of any preceding claim.

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14. A method for manufacturing a cylindrical electromagnet comprising annular coils attached by their radially outer surfaces to an outer mechanical support structure, substantially as described and/or as illustrated in Figs. 3-9 of the accompanying drawings.

5

15. A cylindrical electromagnet substantially as described and/or as illustrated in Figs. 3-9 of the accompanying drawings.

FIG 1A

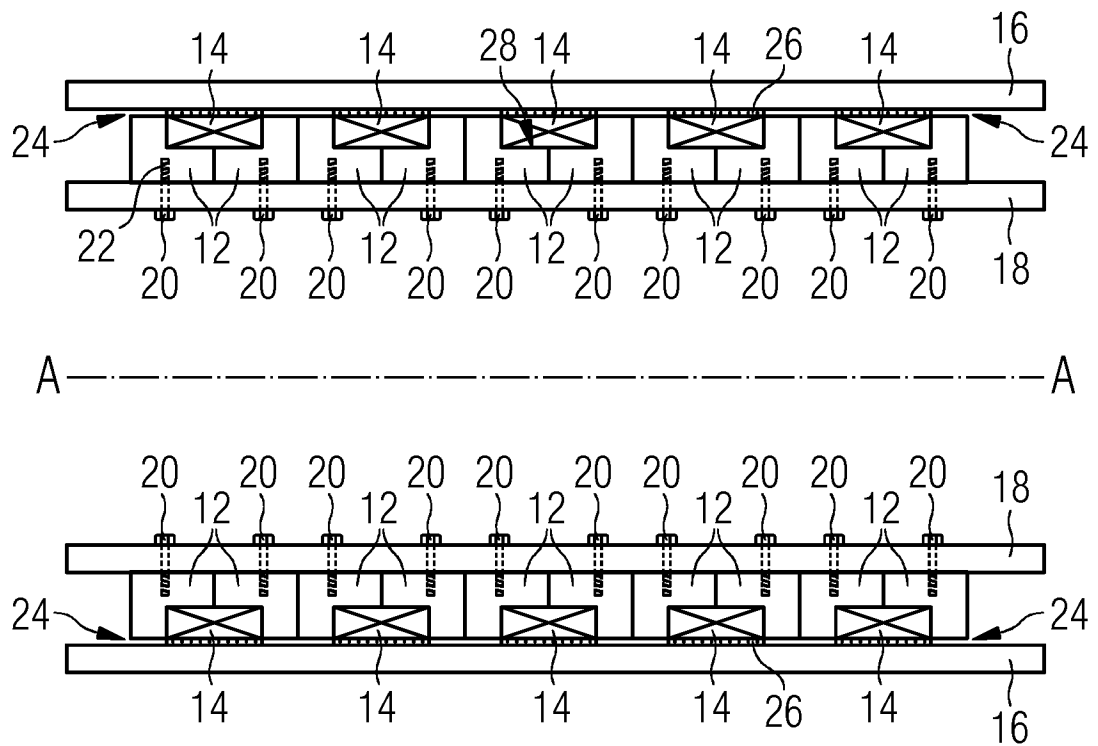


FIG 1B

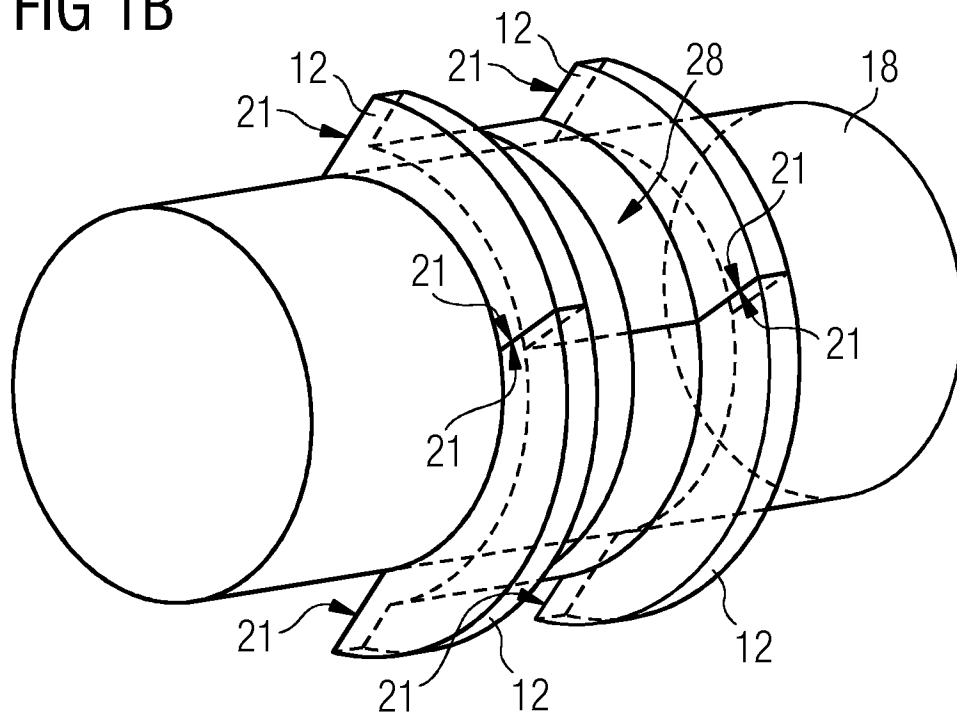


FIG 1C

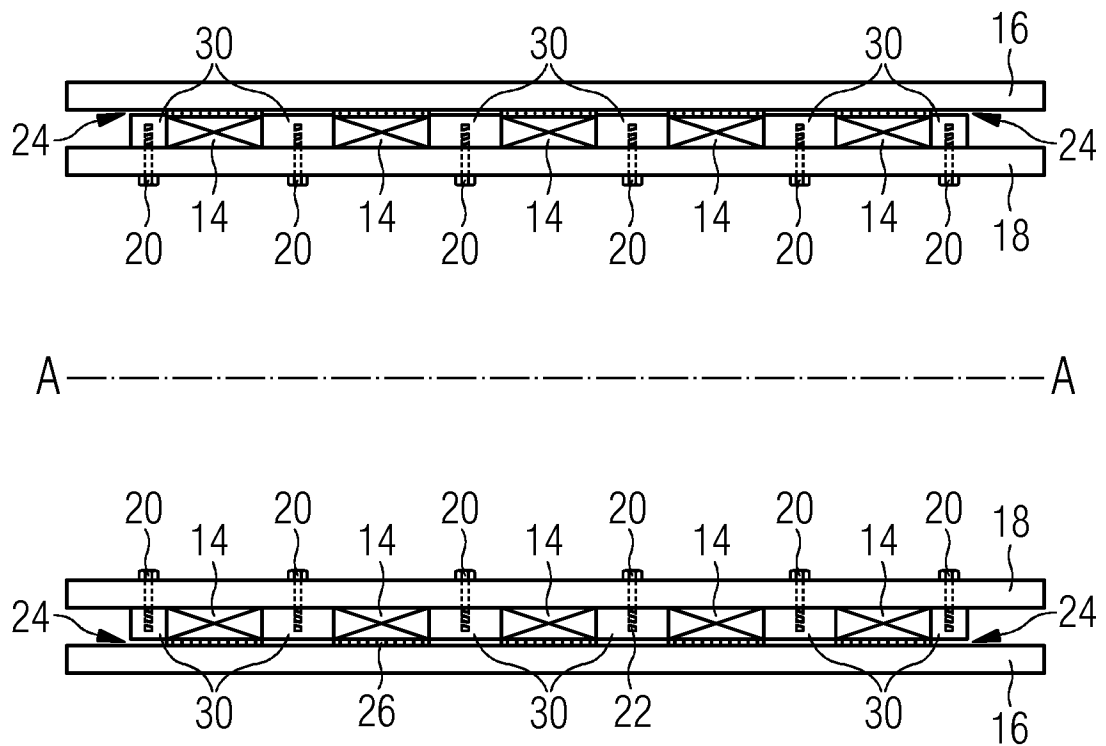


FIG 1D

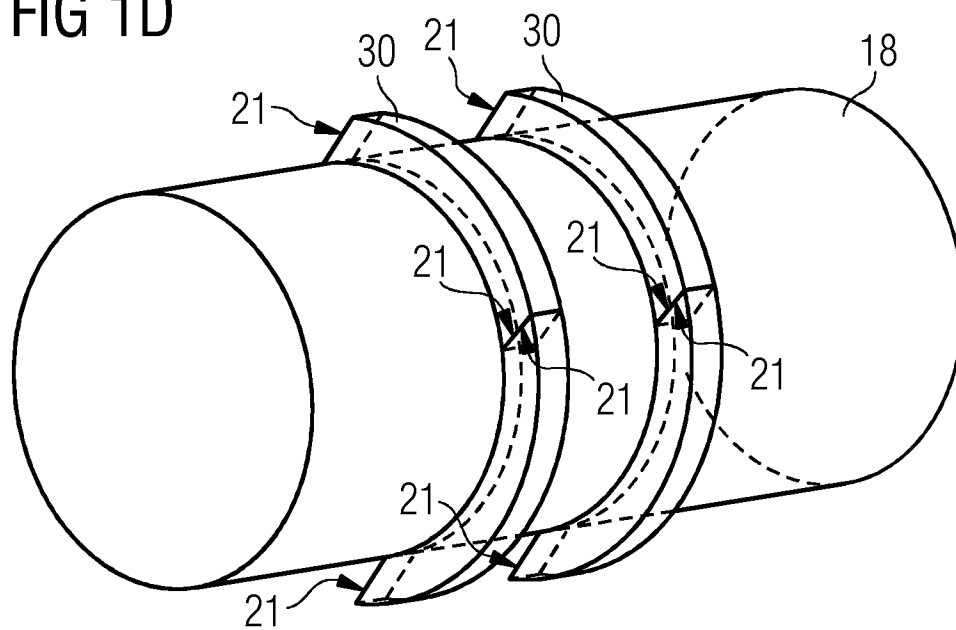


FIG 2

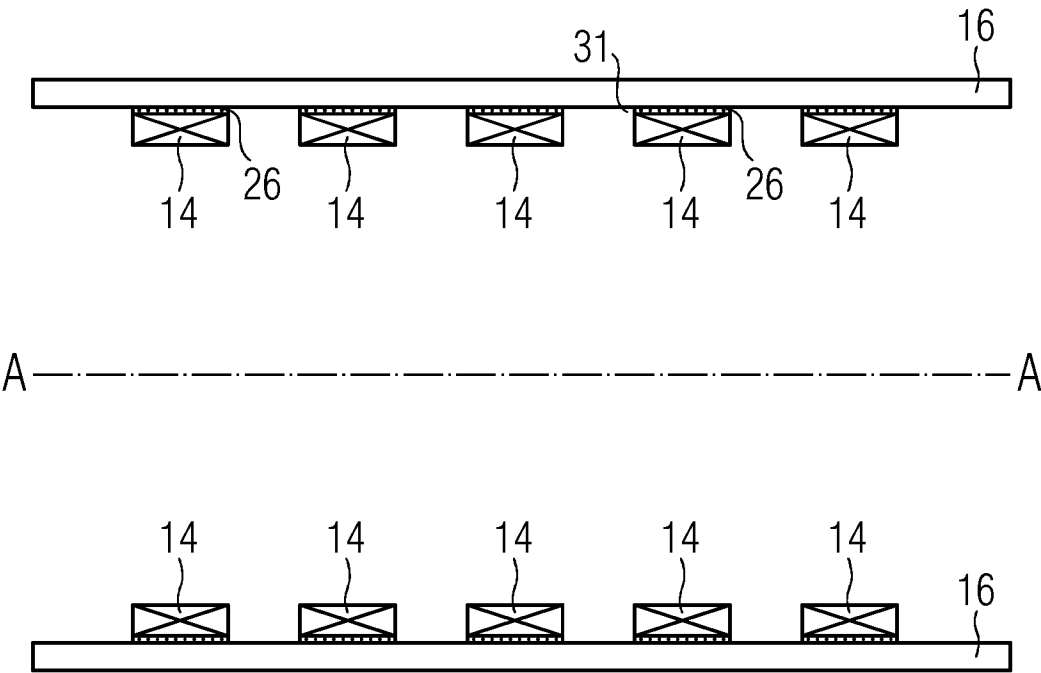


FIG 3A

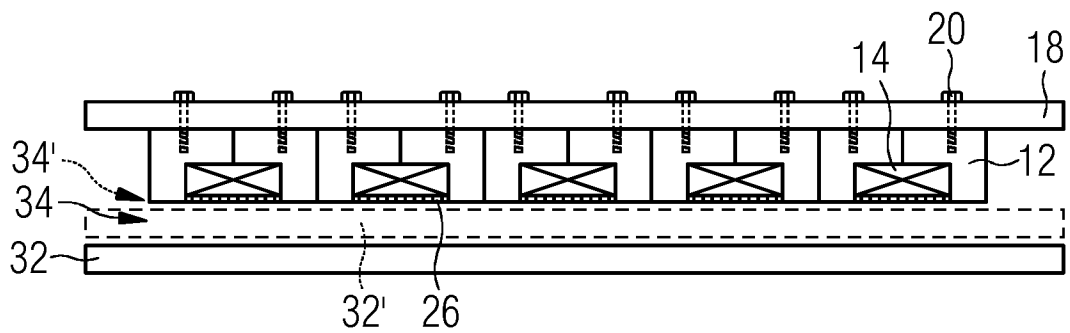
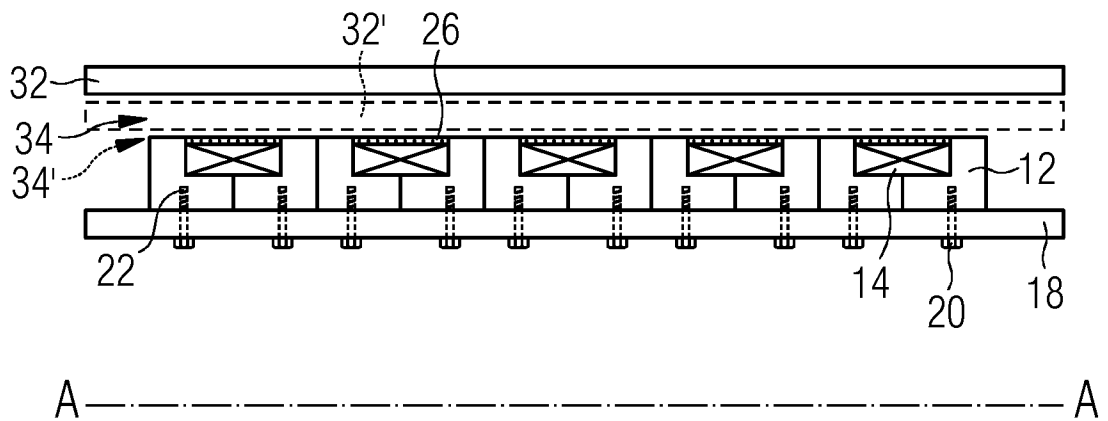


FIG 3B

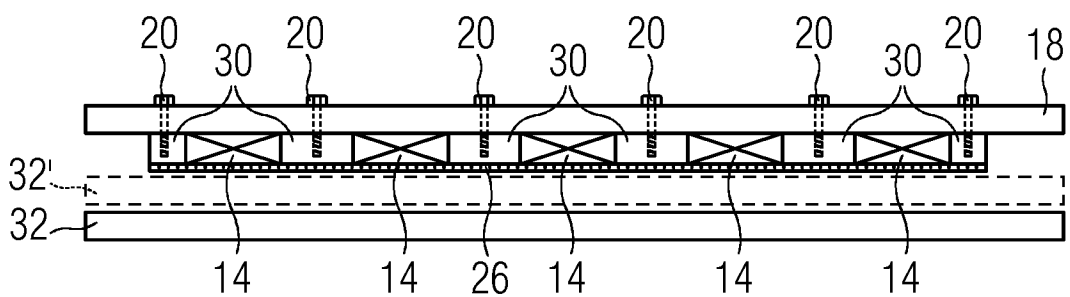
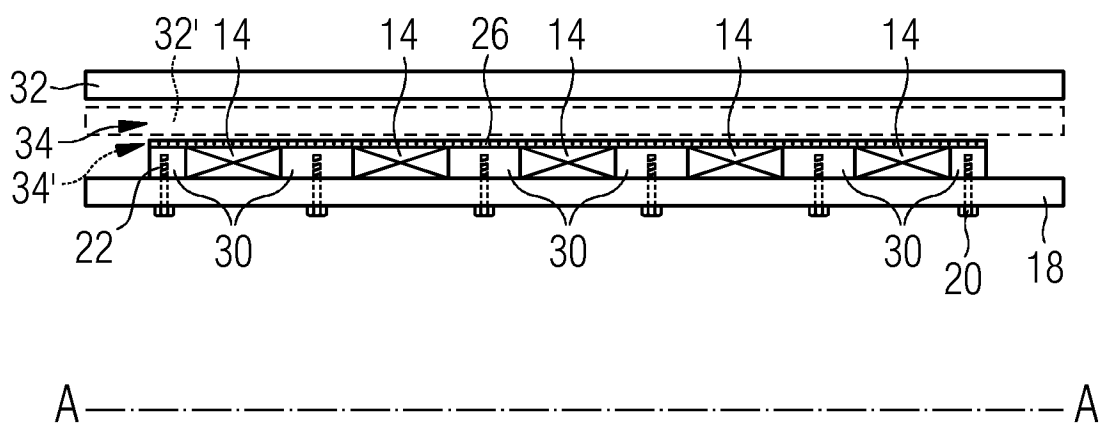


FIG 4A

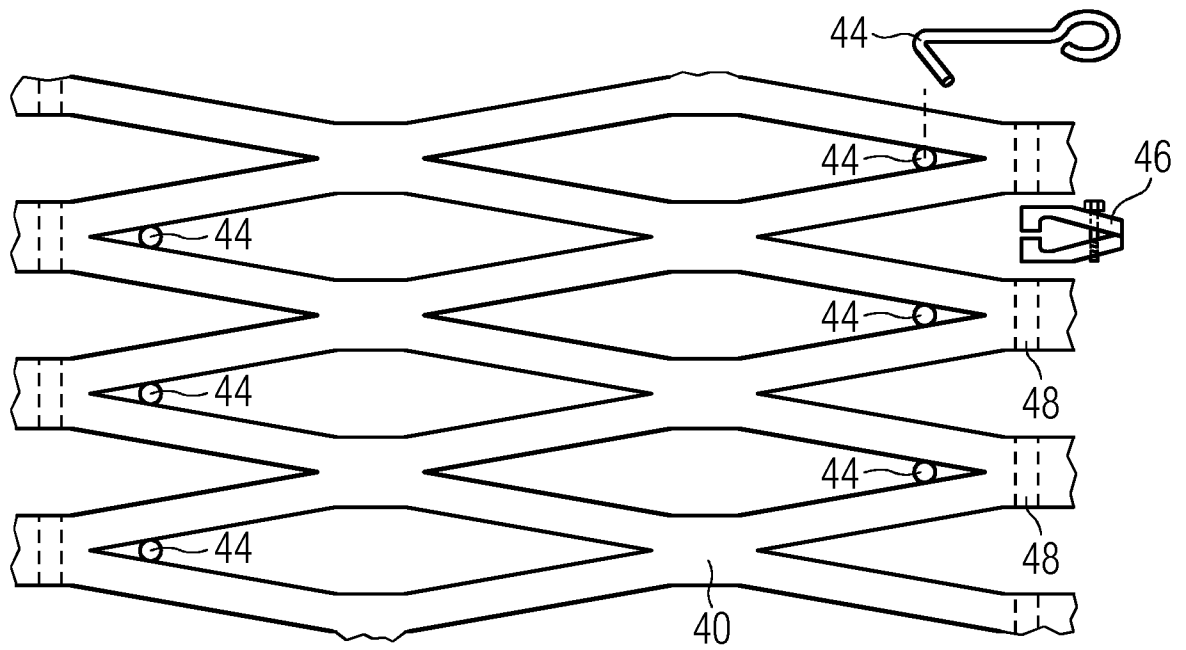


FIG 4B

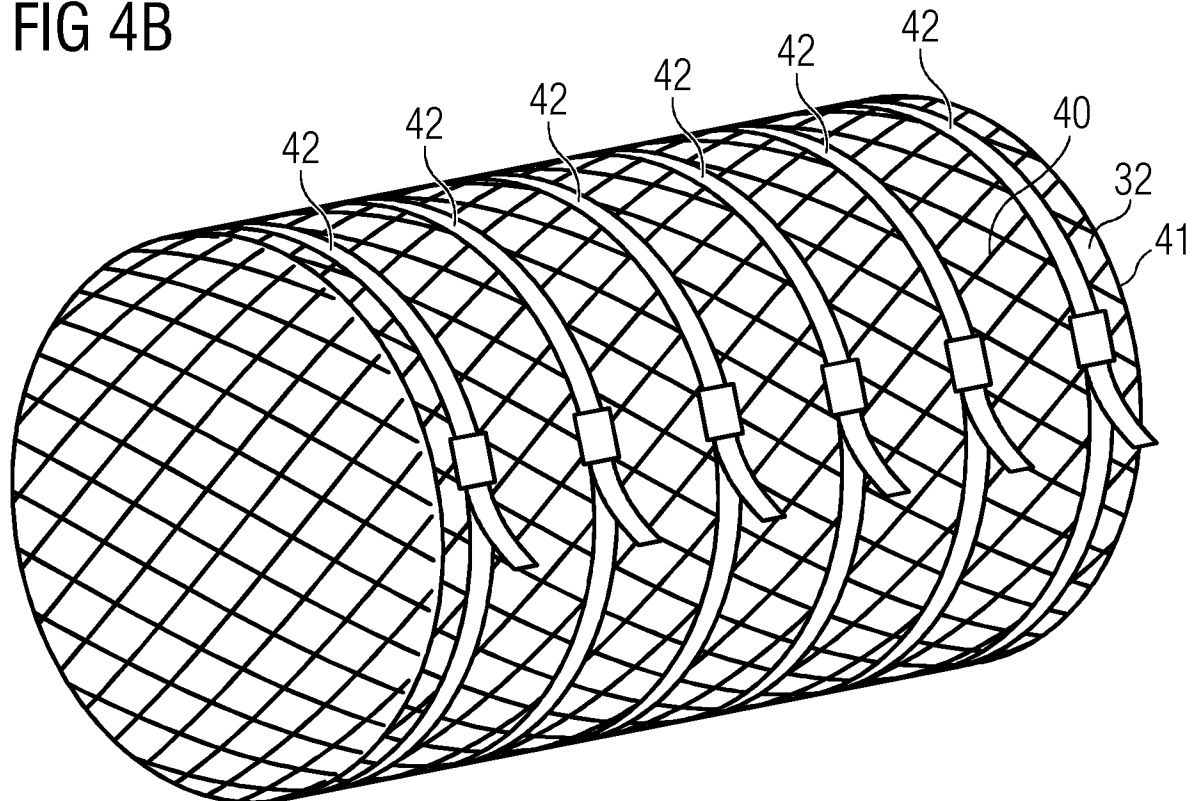


FIG 5A

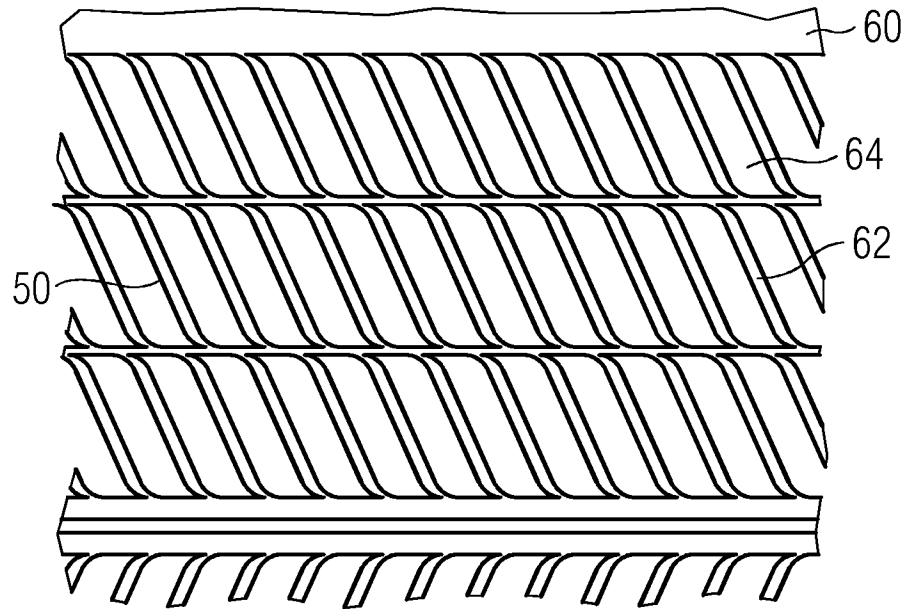
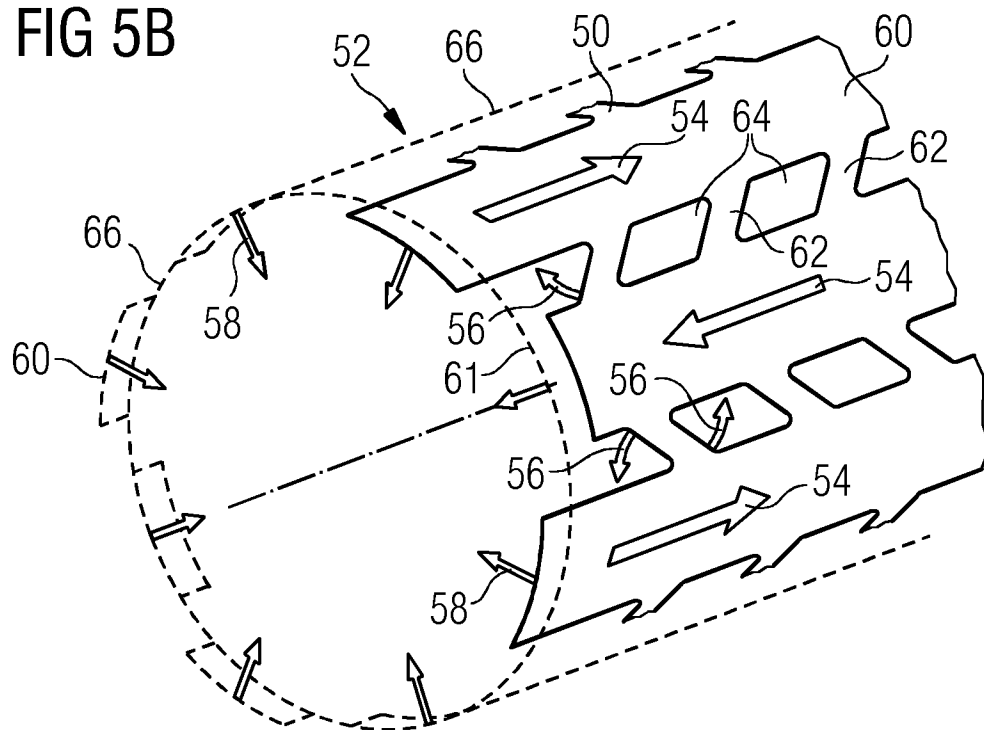


FIG 5B



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FIG 6

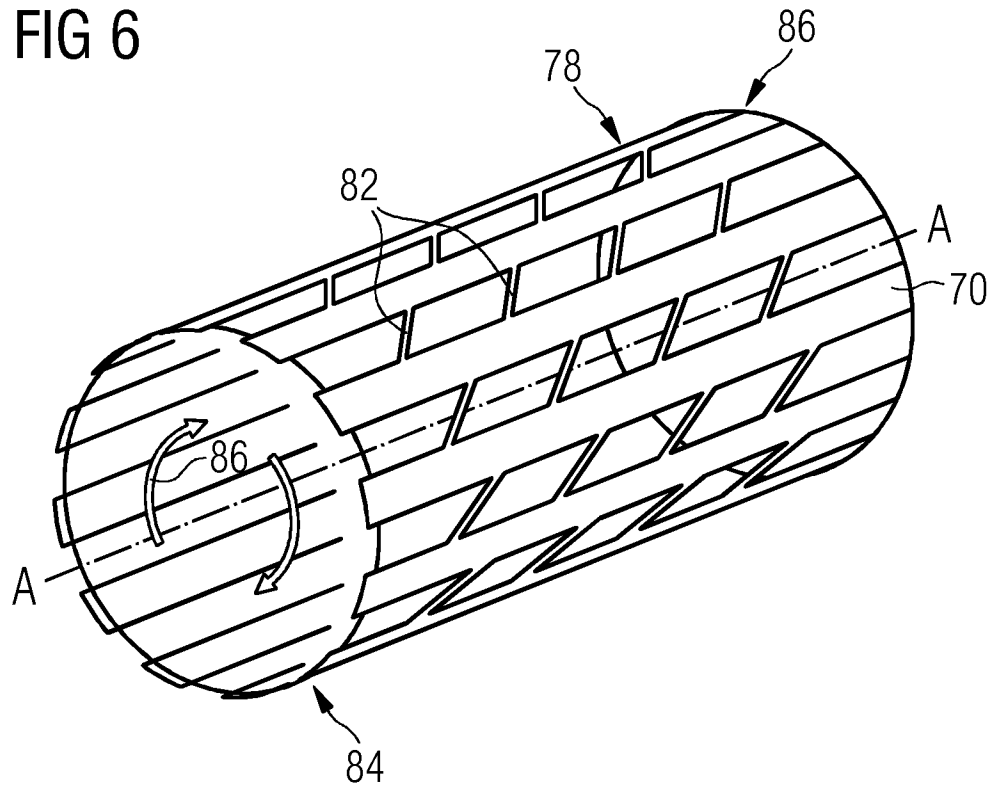


FIG 7

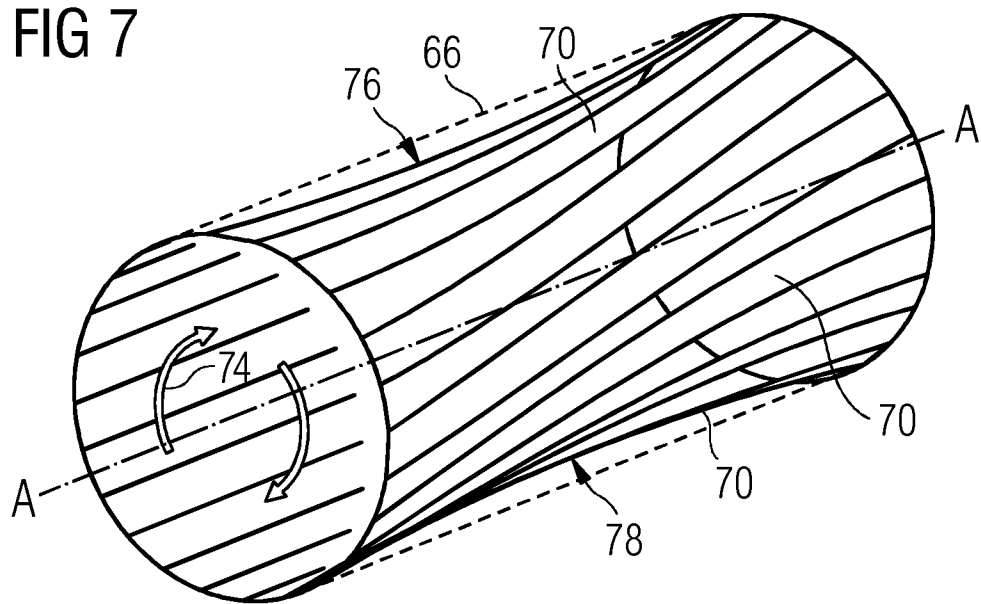


FIG 7A

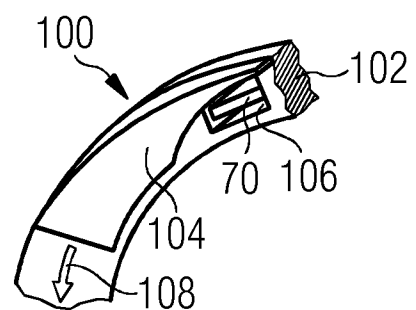


FIG 8

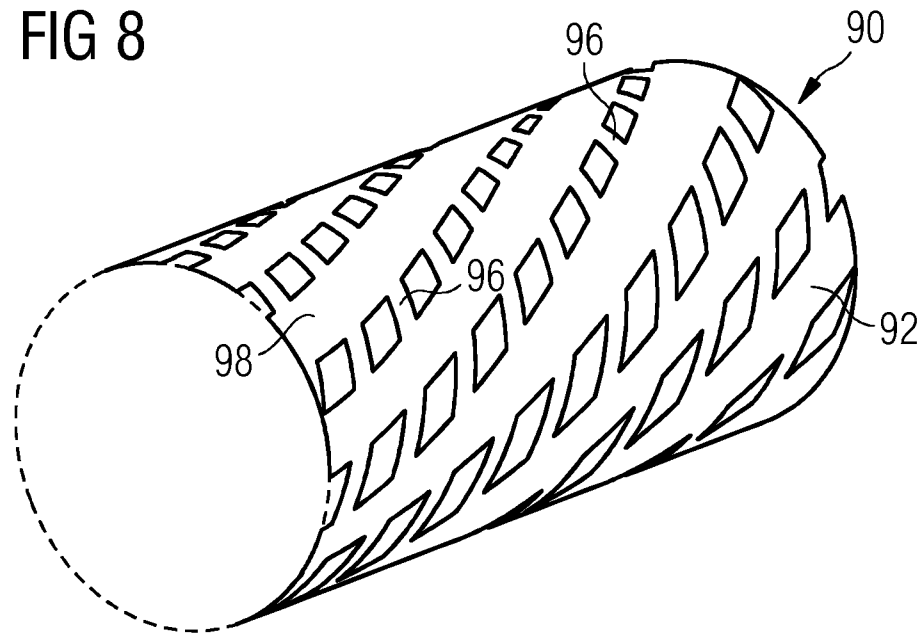
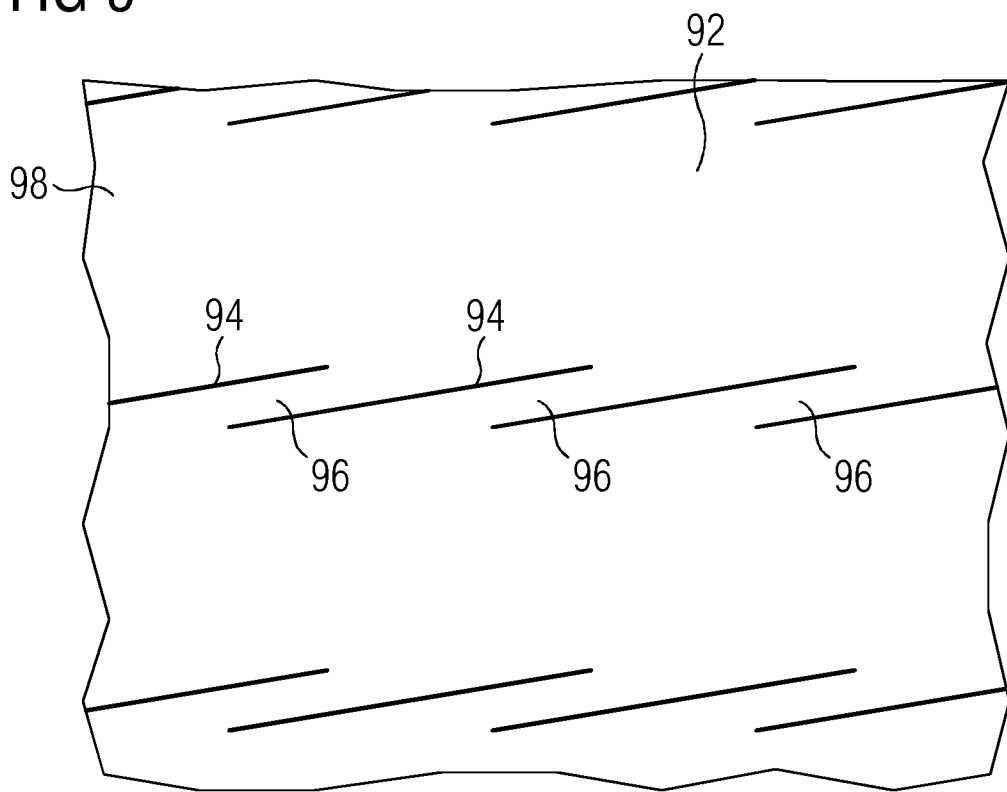


FIG 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2012/050453

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/38 H01F5/02 H01F6/06 G01R33/381 G01R33/3815
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)
G01R 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, BIOSIS, COMPENDEX, EMBASE, INSPEC, IBM-TDB, 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 2011/012698 A1 (HUTTON GRAHAM [GB] ET AL) 20 January 2011 (2011-01-20) paragraph [0015] - paragraph [0026] figure 2	1-4,6-13
A	US 4 896 128 A (WOLLAN JOHN J [US] ET AL) 23 January 1990 (1990-01-23) the whole document	1-13
A	US 4 467 303 A (LASKARIS EVANGELOS T [US]) 21 August 1984 (1984-08-21) the whole document	1-13
A	US 2008/164367 A1 (CALVERT SIMON JAMES [GB]) 10 July 2008 (2008-07-10) the whole document	1-13
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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

11 May 2012

Date of mailing of the international search report

22/05/2012

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Streif, Jörg Ulrich

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2012/050453

Box No. 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.: 14, 15(completely); 13(partially)
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:
see FURTHER INFORMATION sheet PCT/ISA/210
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 No. 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:

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 fees, this Authority did not invite payment of additional fees.
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 and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2012/050453

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/152785 A1 (CALVERT SIMON J [GB] ET AL CALVERT SIMON JAMES [GB] ET AL) 5 July 2007 (2007-07-05) the whole document -----	1-13
A	CN 101 593 597 A (INST ELECTRICAL ENG CAS [CN]) 2 December 2009 (2009-12-02) the whole document -----	1-13
A	JP 62 196802 A (SUMITOMO ELECTRIC INDUSTRIES) 31 August 1987 (1987-08-31) the whole document -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2012/050453

Patent document cited in search report		Publication date		Patent family member(s)		Publication date
US 2011012698	A1	20-01-2011	CN	101958173 A		26-01-2011
			GB	2471882 A		19-01-2011
			JP	2011023724 A		03-02-2011
			US	2011012698 A1		20-01-2011

US 4896128	A	23-01-1990	EP	0371350 A1		06-06-1990
			JP	1672697 C		12-06-1992
			JP	2211608 A		22-08-1990
			JP	3035808 B		29-05-1991
			US	4896128 A		23-01-1990

US 4467303	A	21-08-1984	CA	1228395 A1		20-10-1987
			DE	3477085 D1		13-04-1989
			EP	0118807 A2		19-09-1984
			FI	840376 A		08-09-1984
			IL	70982 A		31-07-1988
			JP	1631120 C		26-12-1991
			JP	2060042 B		14-12-1990
			JP	59175710 A		04-10-1984
			US	4467303 A		21-08-1984

US 2008164367	A1	10-07-2008	CN	101231904 A		30-07-2008
			GB	2444507 A		11-06-2008
			JP	2008147665 A		26-06-2008
			US	2008164367 A1		10-07-2008

US 2007152785	A1	05-07-2007	CN	1992103 A		04-07-2007
			US	2007152785 A1		05-07-2007

CN 101593597	A	02-12-2009	NONE			

JP 62196802	A	31-08-1987	NONE			

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 14, 15(completely); 13(partially)

Concerning claim 13, the scope of the expression "A ... electromagnet ... as may be produced by the method of any preceding claim" is unclear. Therefore, the search of claim 13 was limited to an electromagnet as produced by the method of any preceding claim. Concerning claims 14 and 15, these claims each define a method for manufacturing a cylindrical electromagnet by referring to the description and/or drawings. This definition is so vague and of unclear scope, that no meaningful search could be carried out for these claims.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2) declaration be overcome.