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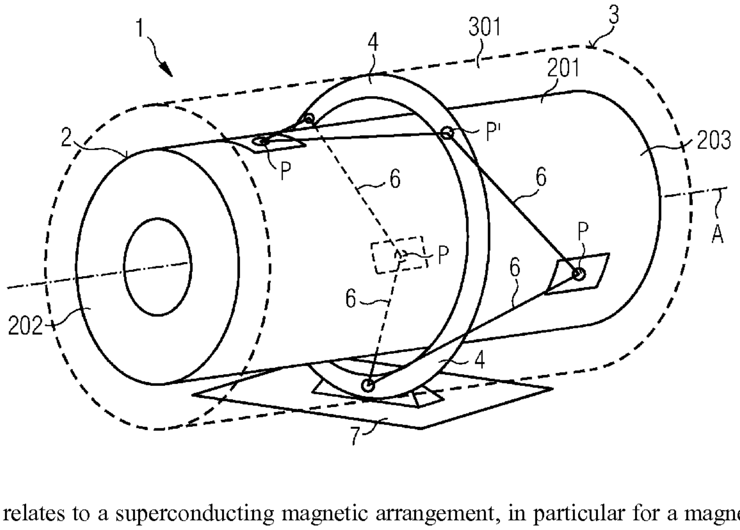
FIG 2



(57) Abstract: The invention relates to a superconducting magnetic arrangement, in particular for a magnetic resonance tomograph, including a magnetic coil unit (2), which comprises a number of superconducting magnetic coils, and a cryostat with an insulating vessel (3) for cooling the magnetic coil unit (2), wherein the magnetic coil unit (2) is arranged in a vacuum in the insulating vessel (3). The magnetic coil unit (2) is held in the interior of the insulating vessel (3) by a maximum of six longitudinal bearing elements (6), which each extend between the magnetic coil unit (2) and the insulating vessel (3) such that a rotary movement and a translatory movement of the magnetic coil unit (2) relative to the insulating vessel (3) is restrained by the bearing elements (6).

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SUPERCONDUCTING MAGNETIC ARRANGEMENT, IN PARTICULAR FOR A MAGNETIC RESONANCE TOMOGRAPH

The invention relates to a superconducting magnetic arrangement, in particular for a magnetic resonance tomograph.

A superconducting magnetic arrangement includes a magnetic coil unit made up of a number of superconducting magnetic coils, the windings of which are made of superconducting material. In order to effect superconductivity in the magnetic coils, the magnetic coil unit is cooled by a cryostat. To this end, the magnetic coil unit is held or suspended in a permanent position in an insulating vessel of the cryostat. The insulating vessel may be a vacuum vessel. It may include a different type of thermal insulation. The suspension is achieved by a number of rods or loops extending between the magnetic coil unit and the insulating vessel of the cryostat. These rods or loops result in heat input into the cooled magnetic coil unit since one end of each of the rods is connected to the relatively warm insulating vessel.

It is the object of the invention to provide a magnetic arrangement in which the magnetic coil unit is held stably in the insulating vessel and simultaneously heat input into the magnetic coil unit is kept low.

This object is achieved by the superconducting magnetic arrangement as claimed in claim 1. Preferred features of certain embodiments of the invention are defined in the dependent claims.

The superconducting magnetic arrangement according to the invention is in particular provided for a magnetic resonance tomograph. It includes a magnetic coil unit comprising a number (i.e. at least one) of superconducting magnetic coils, and a cryostat with an insulating vessel for cooling the magnetic coil unit. The magnetic coil unit may be arranged in a vacuum in the insulating vessel. Depending upon the embodiment, the magnetic coil unit may include a housing. The housing may be a cryogen tank in which the magnetic coils are at least partially immersed in liquid cryogen, such as helium, or are cooled by circulation of gaseous cryogen, such as helium. There are also variants in which the housing is not a cryogen tank, and the magnetic coils are only surrounded by a housing without cryogen filling.

In further embodiments, the magnet coil unit is not provided with any housing, but is directly mounted within the insulating vessel. To cool the magnetic coil unit, liquid cryogen such as helium is generated in a known way via a cooling device of the cryostat and transported via cooling lines to the superconducting windings of the magnetic coils. This may be true of any of the above-described embodiments.

Further known arrangements have coils which are cooled by thermal conduction along a solid conduit. In such an arrangement, a conductive bus bar or laminate or braid or similar is thermally linked between coils at one end and a cryogenic refrigerator at the other end.

In the superconducting magnetic arrangement according to the present invention, the magnetic coil unit is held in the interior of the insulating vessel by a maximum of six longitudinal bearing elements extending between the magnetic coil unit and the insulating vessel such that that rotary movement and translatory movement of the magnetic coil unit relative to the insulating vessel is restrained by the bearing elements. In particular, precisely six bearing elements may be provided, by means of which both the three rotary degrees of freedom and the three translatory degrees of freedom of the movement of the magnetic coil unit with respect to the insulating vessel are restrained with low stress on the bearing elements.

The magnetic arrangement according to the invention has the advantage that, due to the use of a low number of maximum six bearing elements, the heat input into the magnetic coil unit is kept low and, in this way, the cooling efficiency of the cryostat is improved.

In a particularly preferred embodiment, the longitudinal bearing elements are attached to the insulating vessel and the magnetic coil unit such that the bearing elements are each exposed to tensile or compressive stress in their longitudinal direction. Preferably, the bearing elements are each only exposed to force in their longitudinal direction. This can, for example, be achieved by an articulated attachment of the bearing elements to the magnetic coil unit or the insulating vessel. This avoids stress on the bearing elements due to torsion forces or bending forces.

In a particularly preferred embodiment, none of the longitudinal bearing elements is parallel to another bearing element in the longitudinal direction thus achieving stable suspension with a low number of rods.

In some embodiments, the magnetic coil unit includes a housing, wherein the housing of the magnetic coil unit is surrounded by an insulating vessel. In this case, the bearing elements are attached to attachment points on the housing of the magnetic coil unit and to attachment points on the insulating vessel. The attachment points can be provided directly on the corresponding housing and the insulating vessel, but the attachment points can also lie indirectly on the respective housing and insulation vessel, for example using a ring such as described further below.

The shape of the housing can be different from the shape of the magnetic coil unit. Preferably, however, the housing of the magnetic coil unit and also the insulating vessel are cylindrical, at least in sections.

In a particularly preferred embodiment, one end of each of the longitudinal bearing elements is attached to a respective attachment point on a ring attached to the insulating vessel, and the other end of each of the longitudinal bearing elements is attached to a respective attachment point on the magnetic coil unit. The ring extends substantially perpendicularly to the axial direction of a cylindrical magnetic coil unit. Preferably, a subset of the respective attachment points on the magnetic coil unit are offset toward one end and another subset of the respective attachment points on the magnetic coil unit are offset toward the other end of the magnetic coil unit relative to the ring.

The above-described variant of the magnetic arrangement according to the invention achieves a simple design for the magnetic coil unit holder. In this variant, the bearing elements are preferably exposed to tensile stress in their longitudinal direction. The ring used may optionally only be part of an annular section of the insulating vessel without having to have a particular structural embodiment. Similarly, the ring can be an attachment ring in the form of a projection extending from the insulating vessel into the interior of the insulating vessel. The ring is preferably arranged centrally in the axial direction between the two ends of the cylindrical magnetic coil unit. The ring need not be a continuous annular structure, but may be intermittently provided, even as a number of mounting brackets.

In a particularly preferred embodiment, the attachment points of the bearing elements are arranged on the ring symmetrically around the circumference of the ring, i.e. the angle between adjacent attachment points is always the same. This achieves a uniform transmission of force.

In a further particularly preferred embodiment, two bearing elements extend in their longitudinal direction from the ring towards one axial end of the magnetic coil unit, while four bearing elements extend in their longitudinal direction from the ring towards the other axial end of the magnetic coil unit.

In a further variant, three pairs of bearing elements are provided, wherein the bearing elements of a respective pair are attached to attachment points offset with respect to one another around the circumference of the ring and from there converge toward one another in a V-shape in the direction of one or the other axial end of the magnetic coil unit. In this case, the bearing elements of a pair extend in the direction of one axial end of the magnetic coil unit while the bearing elements of the other two pairs extend in the direction of the other axial end of the magnetic coil unit. Preferably, the bearing elements of a respective pair are attached to substantially the same attachment point on the magnetic coil unit. The above-described variant ensures particularly stable holding of the magnetic coil unit with precisely six bearing elements.

In a preferred embodiment, the pairs of bearing elements are arranged in the circumferential direction of the ring adjacent to one another, wherein adjacent bearing elements of different pairs in the circumferential direction are preferably attached to substantially the same attachment point on the ring.

In a further embodiment of the magnetic arrangement according to the invention, the bearing elements extend from respective attachment points on a cylindrical magnetic coil unit to respective attachment points on the insulating vessel in such a manner that the axis of the magnetic coil unit is in a horizontal plane. In this case, the horizontal plane is a plane perpendicular to the force of gravity when the magnetic arrangement is installed as prescribed. The bearing elements preferably extend inclined to the horizontal plane.

In a particularly preferred variant of the above-described embodiment, the attachment points of the bearing elements on the magnetic coil unit are arranged at least partially offset with respect to one another in the axial direction of the cylindrical magnetic coil unit. Preferably, three pairs of bearing elements are provided, wherein the bearing elements of a respective pair are attached to different attachment points on the housing of the magnetic coil unit and converge toward one another in a V-shape toward the insulating vessel. In this case, the bearing elements of a respective pair are preferably attached to substantially the same attachment point on the insulating vessel. Moreover, preferably two bearing elements of two different pairs are attached to substantially the same attachment point on the magnetic coil unit.

The above-described embodiment ensures a stable holding of the magnetic coil unit in the style of a tripod. In an expedient development of this embodiment, in a top view, the attachment points of the bearing elements on the magnetic coil unit form a first triangle on the magnetic coil unit, while, in a top view, the attachment points of the bearing elements on the insulating vessel form a second triangle in the vertical direction on the insulating vessel. In a top view, the first triangle is preferably offset with respect to the second triangle in the vertical direction and offset by rotation, in particular by approximately 180°. This achieves a particularly stable support for the magnetic coil unit. The vertical direction should be understood to mean the direction of the force of gravity when the magnetic arrangement is set up in the prescribed manner, and the horizontal direction should be understood as being perpendicular to the vertical direction.

In a further embodiment of the magnetic arrangement according to the invention, the bearing elements are rods or loops that can be subjected to tensile and/or compressive stress, wherein the loops are preferably O-shaped or in the shape of the figure “8”. Preferably fiber-reinforced plastic is used as the material for the bearing elements.

In a further preferred variant, the bearing elements each include a non-linear spring element or are embodied as non-linear spring elements, wherein the spring stiffness of the non-linear spring element reduces in the longitudinal direction of the respective bearing element when forces exerted on the respective bearing element exceed forces exerted on the bearing elements in the resting position of the magnetic arrangement. This achieves a relatively rigid holding of the magnetic coil unit in the resting position, wherein, however, in the case of additional forces, such as, for example, in the case of vibrations induced in the operation of the magnetic arrangement, the application of force on the sensitive magnetic coils is reduced.

In a particularly preferred embodiment, the non-linear spring elements in the respective bearing elements are arranged closer to the insulating vessel than to the magnetic coil unit. Hence, the bearing elements are located on the warm side the magnetic arrangement adjacent to the insulating vessel so that cold-induced brittleness of the spring material of the non-linear spring elements is avoided.

Exemplary embodiments of the invention are described in detail below with reference to the attached figures, which show:

Fig. 1 a schematic view of a superconducting magnetic arrangement not according to the present invention;

Fig. 2 a schematic view of a superconducting magnetic arrangement according to a first embodiment of the invention; and

Fig. 3 a schematic view of a superconducting magnetic arrangement according to a second embodiment of the invention.

The following describes embodiments of the invention based on a superconducting magnetic arrangement used in a magnetic resonance tomograph. First, a superconducting magnetic arrangement, not according to the present invention is explained with reference to Fig. 1.

The magnetic arrangement 1 in Fig. 1 includes a cylindrical magnetic coil unit 2 with an optional cryogen tank or other housing 201 and a front end 202 and a rear end 203. The housing 201 contains a plurality of magnetic coils with superconducting windings arranged one behind the other in the direction of the axis of symmetry or longitudinal axis A of the cylindrical arrangement. The magnetic coils are suspended at least partially immersed in liquid cryogen in the housing 201. The magnetic coils are cooled by a cryostat which includes an insulating vessel 301 which, similarly to the magnetic coil unit 2, is preferably embodied cylindrically and indicated by dashed lines in Fig. 2. In other embodiments, no cryogen tank or other housing is provided, and the magnetic coils may be suspended within the insulating vessel without a cryogen tank or outer housing.

Both the magnetic coil unit 2 and the insulating vessel 3 are provided with a central through-hole around the axis A to accommodate a patient for the performance of examinations based on magnetic resonance tomography in the arrangement.

In addition to the insulating vessel 3, the cryostat includes a cooling device, which is not shown in Fig. 1 but is typically arranged above the magnetic arrangement. In embodiments with no cryogen tank, the cooling device uses a cooling circuit with lines that run in contact with the magnetic coil unit to cool the magnetic coils. For insulation, the magnetic coil unit is located inside the insulating vessel, which is preferably evacuated although other forms of thermal insulation may be provided in addition to, or instead of, a vacuum.

To mount the magnetic coil unit 2 in the insulating vessel 3, two circumferential attachment rings 4 are provided along the container 3. The magnetic coil unit 2 is suspended on the rings 4 by bearing elements such as rods or optionally also loops. These could be made of any material, such as a plastic or a glass- or carbon- fibre reinforced plastic, providing that both the strength and the thermal conductivity specifications are acceptable. Such rods and/or loops could be of steel, for example, providing that acceptable strength and the thermal conductivity parameters are met through design.

The respective rods extend between attachment points P on the magnetic coil unit 2 and attachment points P' on the respective two rings 4. In the arrangement in Fig. 1, the individual rods 6 are exposed to tensile stress and a large number of these rods are present. Typically, twelve such rods are used. Moreover, two supporting feet 5 are embodied on the rings 4 in each case so that the arrangement rests on a total of four supporting feet.

In the arrangement in Fig. 1, the magnetic coil unit 2 is the so-called cold mass, which is to be cooled with the lowest possible heat losses. In this case, however, the rods 6 represent a significant heat source to the cold mass. In order to minimize the heat input to the cold mass, the rods or loops are embodied thin and long. A further boundary condition with respect to the embodiment of the rods is imposed by the mechanical stress on the suspension of the cold mass, wherein during transportation of the arrangement, greater forces can occur than in stationary operation. It is also desirable for the suspension only to input low mechanical forces in the frequency range above one hertz into the cold mass. As a rule, such mechanical forces are caused by vibrations during the operation of the arrangement.

In the arrangement in Fig. 1, there is a problem that, due to the high number of suspension rods 6, there is also a relatively high heat input into the cold mass. Within the context of the embodiments described in the following, this heat input is reduced by limiting the number of rods 6 as will be explained with reference to Fig. 2 and Fig. 3.

In the embodiment in Fig. 2, and also in the variant in Fig. 3 described further below, use is made of the knowledge that the conventional construction in Fig. 1 is hyperstatic because, for the suspension the cold mass 2 in the insulating vessel 3, it is necessary to take account of only six degrees of freedom, three rotary degrees of freedom and three translatory degrees of freedom, to restrain the relative movement of the magnetic coil unit 2 with respect to the insulating vessel 3. However, to this end, the arrangement in Fig. 1 has a significantly higher number of rods than six.

Now, in the embodiment in Fig. 2, only six rods are used to suspend the magnetic coil unit 2 in the insulating vessel 3. This number is sufficient to suppress all translatory and a rotary relative movements of the magnetic coil unit with respect to the insulating vessel 3. Otherwise, the arrangement in Fig. 2 is similarly constructed to the arrangement in Fig. 1. In particular, the same magnetic coil unit 2 may include an optional housing 201 and two ends 202 and 203.

However, unlike the case in Fig. 1, the insulating vessel 3 in Fig. 2 now only includes one ring 4, which is embodied in the direction of the longitudinal axis A centrally between the two ends of the magnetic coil unit 2 or of the insulating vessel 3 in the interior of the insulating vessel 3. This ring 4 is attached together with the insulating vessel 3 on a base plate

7 by means of which the arrangement in Fig. 2 is installed. The ring 4 is in turn used for attachment to the rods 6, wherein three attachment points P' offset with respect to one another are provided on the ring. The ends of two rods are located on each attachment point. Nevertheless, the rod ends do not have to be attached to exactly the same attachment point. Moreover, on the magnetic coil unit 2, there are three attachment points P at which in each case two rods 6 terminate. Nevertheless, the rods can also be attached individually to attachment points offset with respect to one another.

The rods 6 are in turn exposed to tensile stress and can also be formed as loops of fiber-reinforced plastic. The six rods form three pairs of rods, wherein one end of the rods of a respective pair is attached to a common attachment point P on the magnetic coil unit 2 and from there they extend in a V-shape toward different attachment points P' on the ring 4. The attachment points P of two of the three pairs are arranged in the direction of the axis A behind the ring in the drawing, toward the end 203 and below the cylindrical axis A of the magnetic coil unit 2. On the other hand, the attachment point P of the third pair is arranged in the direction of the axis A in front of the ring in the drawing, toward the end 202 and above the cylindrical axis A of the magnetic coil unit 2.

The individual rods of the respective pairs extend in the style of bicycle spokes with a very low angle (i.e. almost tangentially) from the respective attachment points P toward the attachment points P'. The attachment of the rods to the attachment points P or P' is preferably articulated so that the individual rods are exclusively exposed to tensile stress and no torsion forces or bending forces are transmitted. This achieves low stress on the individual rods with a simultaneously reduced number of rods. Hence, the arrangement in Fig. 2 is a simple and efficient way to achieve the suspension of the cold mass 2 in the insulating vessel 3 and, at the same time, keep the heat input via the rods into the cold mass low.

Fig. 3 shows a second embodiment of the magnetic arrangement according to the invention. The arrangement includes the same magnetic coil unit 2 with optional outer housing 201 as that in Fig. 2. This magnetic coil unit is in turn surrounded by the insulating vessel of a cryostat. However, for reasons of simplicity, the insulating vessel is not shown in Fig. 3. The insulating vessel extends around the magnetic coil unit 2 and has suitable bulges in the lower part in which the attachment points P' depicted are located. The ends of the bulges with the attachment points P' located therein are attached to the base plate 7 on which the magnetic arrangement stands. Alternatively, the insulating vessel 3 may include an extended region, which may be planar and may be used as, or attached to, base plate 7.

Analogously to the embodiment in Fig. 2, in Fig. 3 again only six rods 6 are used to prevent the translatory or rotary movement of the magnetic coil unit 2 with respect to the insulating vessel 3. However, in the embodiment of Fig. 3, all the rods 6 are compression rods which are exposed to pressure from the weight of the magnetic coil unit 2. The rods are attached to the insulating vessel at the above-mentioned attachment points P' of which a total of three are provided at which in each case the ends of two rods are located. For attachment on the magnetic coil unit 2, once again three attachment points P are provided, wherein once again the ends of two rods are arranged at each attachment point. The individual rods 6 extend inclined to the horizontal direction, i.e. inclined to the direction of the plane of the base plate 7. Preferably, and as illustrated, the rods and the attachment points P, P′ are all located below the cylindrical axis A of the magnetic coil unit 2.

The arrangement in Fig. 3 holds the magnetic coil unit 2 in the style of a tripod. This tripod is formed by three pairs of rods 6, wherein the rods of a respective pair start at a common attachment point P' on the base plate or insulating vessel 3 and extend toward separate attachment points P on the magnetic coil unit 2. Two of the attachment points P are located closer to the “front” end 202 of the housing 201, as viewed in Fig. 3, than the further attachment point, which is arranged closer to the “rear” end 203 of the housing 201, as viewed in Fig. 3. In order to ensure that no torsion forces act on the rods, the latter are preferably mounted in an articulated manner on the individual attachment points P or P'. In embodiments where the optional outer housing 201 is not provided, two of the attachment points P are located closer to the “front” end of the magnetic coil unit 2 than the further attachment point, which is arranged closer to the “rear” end of the magnetic coil unit 2.

Unlike the case in the embodiment in Fig. 2, in Fig. 3, the rods 6 in Fig. 3 are exposed to compressive stress. Hence, the rods 6 may be embodied more rigidly in embodiments such as shown in Fig. 3 than the rods in embodiments such as shown in Fig. 2, which are exposed to tensile stresses. The materials used for the rods in the two embodiments in Fig. 2 and Fig. 3 can be fiber-reinforced plastic. When the rods are embodied in loop shape, the fibers can be wound in an O-shape or 8-shape thus achieving uniform stress on all fibers and avoiding concentrated loads.

In a special embodiment, so-called non-linear spring elements are integrated within the rods in Fig. 2 or Fig. 3. Spring elements of this kind are, for example known, from publication DE 103 32 833 B4. The non-linear spring elements have reducing spring stiffness in the longitudinal direction of the respective rod when the forces exerted on the respective rod exceed the forces exerted on the rods in the resting position of the magnetic arrangement. Hence, a high stiffness is achieved with the base load of the rods, wherein, however, in the case of loads that exceed this, such as, for example, in the case of forces caused by vibrations, the spring stiffness decreases thus reducing the transfer of force onto the sensitive magnetic coils in the magnetic coil unit. The individual spring elements in the rods are preferably arranged closer to the insulating vessel than to the magnetic coil unit. This prevents an excessively close arrangement on the cold side of the rods resulting in increasing brittleness of the spring material of the spring elements.

The above-described embodiments of the invention have a series of advantages. In particular, a low number of only six rods can achieve suspension of the cold mass in the insulating vessel such that all rotary and translatory movements of the magnetic coil unit with respect to the insulating vessel are restrained. In this case, due to the low number of rods, the heat input from the rods into the cold mass is low. In addition, due to the use of non-linear spring elements in the rods, the transmission of force by vibrations onto the magnetic coil unit during the operation of the arrangement can be reduced.

Claims

1. A superconducting magnetic arrangement including a magnetic coil unit (2), which comprises a number of superconducting magnetic coils, and an insulating vessel (3), wherein the magnetic coil unit (2) is arranged in the insulating vessel (3),
characterized in that
the magnetic coil unit (2) is held in the interior of the insulating vessel (3) by a maximum of six longitudinal bearing elements (6), which each extend between the magnetic coil unit (2) and the insulating vessel (3) such that rotary movement and translatory movement of the magnetic coil unit (2) relative to the insulating vessel (3) is restrained by the bearing elements (6).

2. The superconducting magnetic arrangement according to claim 1, wherein the insulating vessel (3) is a vacuum vessel.

3. The magnetic arrangement as claimed in claim 1 or claim 2, characterized in that the magnetic coil unit (2) is held by precisely six longitudinal bearing elements (6) in the interior of the insulating vessel (3).

4. The magnetic arrangement as claimed in any preceding claim, characterized in that the bearing elements (6) are attached to the insulating vessel (3) and the magnetic coil unit (2) such that the bearing elements (6) are exposed to stress in their longitudinal direction.

5. The superconducting magnetic arrangement according to claim 4, wherein each bearing element is exposed to one of: tensile stress; and compressive stress.

6. The superconducting magnetic arrangement according to claim 5, wherein each bearing element is exposed to compressive stress.

7. The magnetic arrangement as claimed in one of the preceding claims, characterized in that none of the bearing elements (6) is parallel to another bearing element (6) in the longitudinal direction.

8. The magnetic arrangement as claimed in one of the preceding claims, characterized in that the magnetic coil unit (2) has two opposite ends (202, 203) and the magnetic coil unit (2) is surrounded by the insulating vessel (3), wherein the bearing elements (6) are attached to attachment points (P) on the magnetic coil unit (2) and to attachment points (P') on the insulating vessel (3).

9. The magnetic arrangement as claimed in claim 8, characterized in that the magnetic coil unit (2) is cylindrical and/or the insulating vessel (3) is cylindrical, about an axis A.

10. The magnetic arrangement as claimed in claim 9, characterized in that one end of each of the bearing elements (6) is attached to a ring (4) on the insulating vessel (3) at respective attachment points (P') and the other end of each of the bearing elements is attached at a respective attachment point (P) on the magnetic coil unit (2), wherein the ring (4) substantially extends perpendicularly to the axis (A) of the magnetic coil unit (2), and a subset of the respective attachment points (P) on the magnetic coil unit (2) are partially offset toward one end (202) and another subset of the respective attachment points (P) on the housing (201) of the magnetic coil unit (2) are partially offset toward the other end (203) of the magnetic coil unit (2) relative to the ring (4).

11. The magnetic arrangement as claimed in claim 10, characterized in that the ring (4) is one or more projection extending from the insulating vessel (3) into the interior of the insulating vessel (3).

12. The magnetic arrangement as claimed in claim 10 or 11, characterized in that the attachment points (P') of the bearing elements (6) are arranged on the ring (4) symmetrically around the circumference of the ring (4).

13. The magnetic arrangement as claimed in one of claims 10 to 12, characterized in that two bearing elements (6) extend in their longitudinal direction from the ring (4) towards one end (202) of the magnetic coil unit (2) and four bearing elements (6) extend in their longitudinal direction from the ring (4) towards the other end (202) of the magnetic coil unit (2).

14. The magnetic arrangement as claimed in one of claims 10 to 13, characterized in that three pairs of bearing elements (6) are provided, wherein the bearing elements (6) of a respective pair are attached at attachment points (P') offset with respect to one another along the circumference of the ring (4) and converge toward each other in a V-shape in the direction of an end (202, 203) of the magnetic coil unit (2), wherein the bearing elements (6) of a pair extend in the direction of one end (202) of the magnetic coil unit (2) and the bearing elements (6) of the other two pairs extend in the direction of the other end (202) of the magnetic coil unit (2), wherein the bearing elements (6) of a respective pair are preferably attached to substantially the same attachment point (P) on the magnetic coil unit (2).

15. The magnetic arrangement as claimed in claim 14, characterized in that the pairs of bearing elements (6) are arranged adjacent to one another in the circumferential direction of the ring (4), wherein adjacent bearing elements of different pairs (6) in the circumferential direction are preferably substantially attached to the same attachment point (P') on the ring (4).

16. The magnetic arrangement as claimed in one of the preceding claims in combination with either claim 8 or claim 9, characterized in that the bearing elements (6) extend from respective attachment points (P) on the magnetic coil unit (2) to respective attachment points (P') on the insulating vessel (3) such that the magnetic coil unit (2) is supported by the bearing elements (6), with cylindrical axis A extending in a horizontal plane.

17. The magnetic arrangement as claimed in claim 16, wherein the bearing elements (6) extend inclined to the horizontal plane.

18. The magnetic arrangement as claimed in claim 16 or claim 17, characterized in that the attachment points (P) of the bearing elements (6) are arranged offset to one another on the magnetic coil unit (2) at least partially in the axial direction of the magnetic coil unit (2).

19. The magnetic arrangement as claimed in claim 1, characterized in that three pairs of bearing elements (6) are provided, wherein the bearing elements (6) of a respective pair are attached to different attachment points (P) on the magnetic coil unit (2) and converge toward one another in a V-shape toward the insulating vessel (3), wherein the bearing elements (6) of a respective pair are preferably attached to substantially the same attachment point (P') on the insulating vessel (3) and two bearing elements (6) of two different pairs are preferably attached to substantially the same attachment point (P) on the magnetic coil unit (2).

20. The magnetic arrangement as claimed in one of claims 16 to 19, characterized in that, in a top view, the attachment points (P) of the bearing elements (6) on the magnetic coil unit (2) form a first triangle and, in a top view, the attachment points (P') of the bearing elements (6) on the insulating vessel (3), form a second triangle , wherein, in a

top view, the first triangle is offset with respect to the second triangle in the vertical direction.

21. The magnetic arrangement as claimed in claim 20, wherein the first triangle is offset by rotation by approximately 180°.

22. The magnetic arrangement as claimed in claim 20 or claim 21, wherein the magnetic coil unit (2) is cylindrical about an axis A, and the attachment points (P) of the bearing elements (6) on the magnetic coil unit (2); and the attachment points (P') of the bearing elements (6) on the insulating vessel (3), and the bearing elements, are all located below the axis A in the vertical direction.

23. The magnetic arrangement as claimed in one of the preceding claims, characterized in that the bearing elements (6) are rods or loops that can be exposed to tensile and/or compressive stress, wherein the loops are O-shaped or in the shape of the figure “8”.

24. The magnetic arrangement as claimed in one of the preceding claims, characterized in that the bearing elements (6) each include a non-linear spring element and/or are embodied as a non-linear spring element, wherein the spring stiffness of the non-linear spring element reduces in the longitudinal direction of the respective bearing element (6) when forces exerted on the respective bearing element (6) exceed forces exerted on the bearing elements (6) in the resting position of the magnetic arrangement (1).

25. The magnetic arrangement as claimed in claim 24, characterized in that the non-linear spring elements in the respective bearing elements (6) are arranged closer to the insulating vessel than to the magnetic coil unit (2).

FIG 1

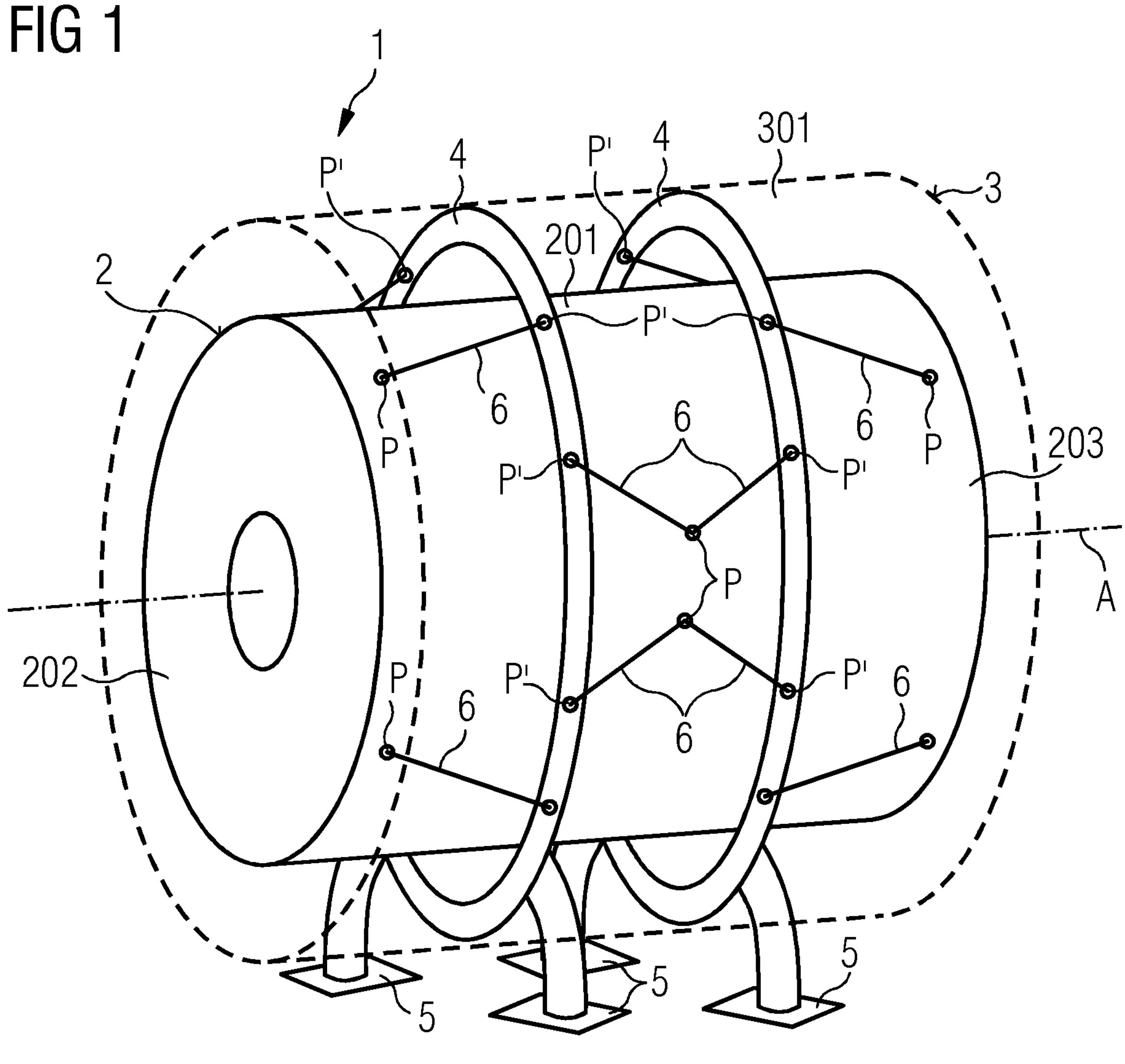


FIG 2

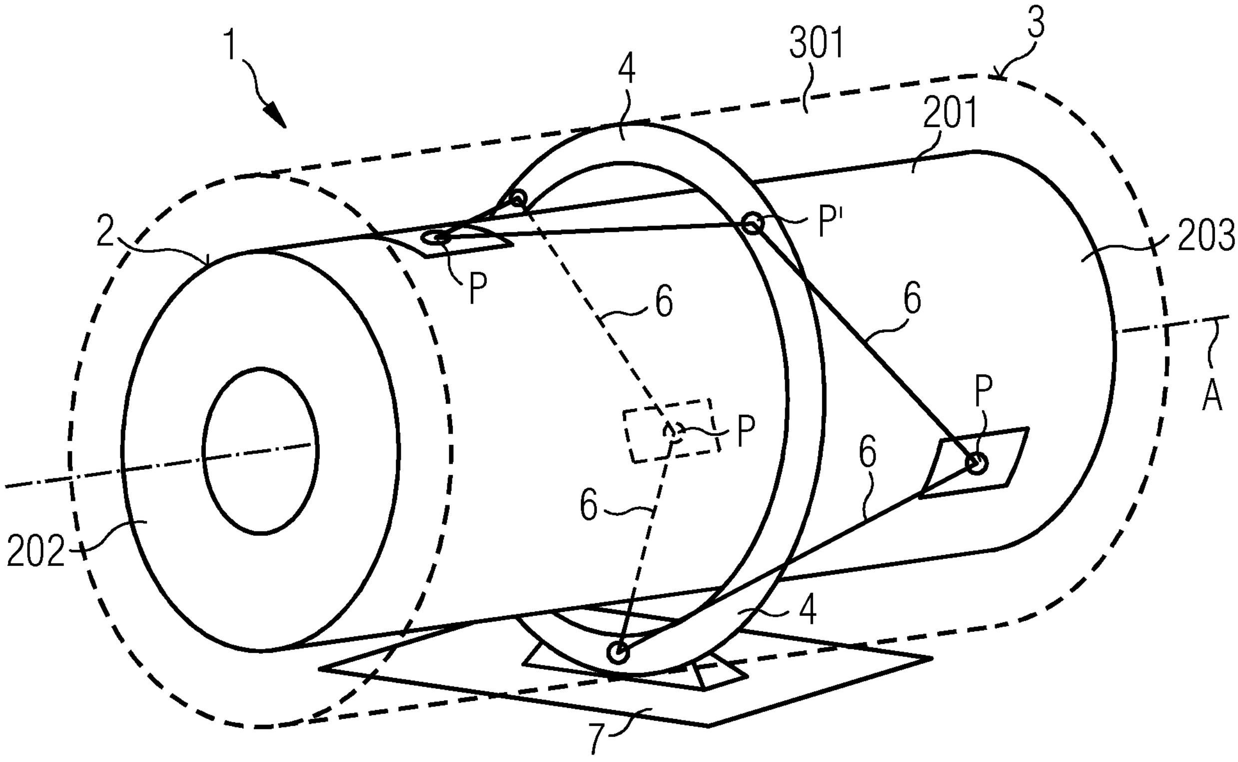
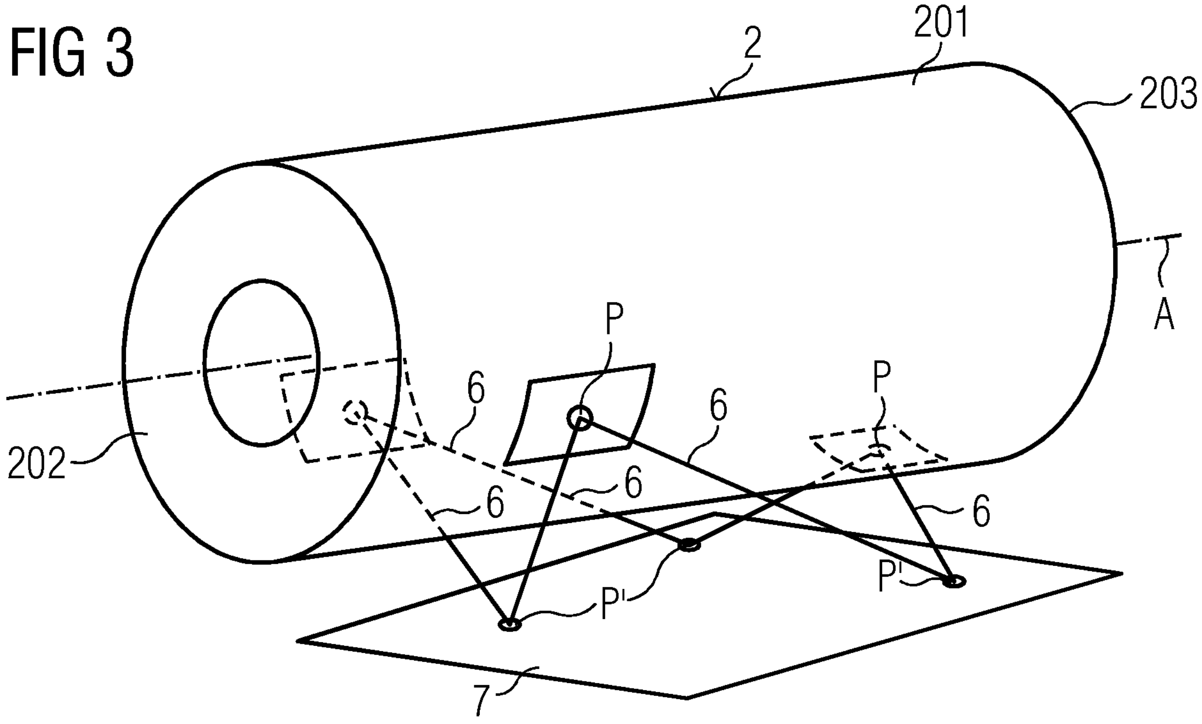


FIG 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/051665

A. CLASSIFICATION OF SUBJECT MATTER
INV. F17C3/08
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 F16C F17C

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 4 516 405 A (LASKARIS EVANGELOS T [US]) 14 May 1985 (1985-05-14) column 1, lines 7 - 16 column 2, lines 3 - 20 column 4, lines 6 - 12 column 6, lines 57 - 62 figures 1, 2 -----	1-9, 16-18, 23-25
X	GB 2 440 350 A (SIEMENS MAGNET TECHNOLOGY LTD [GB]) 30 January 2008 (2008-01-30) page 1, lines 4 - 12 page 2, lines 1 - 9 page 3, lines 16 - 20 page 4, lines 4 - 29 figures 1, 2 ----- -/--	1-6,8,9, 16,17, 22,23

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 April 2016	04/05/2016

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, Fax: (+31-70) 340-3016	Van den Berg, G

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 0 156 017 A1 (SIEMENS AG [DE]) 2 October 1985 (1985-10-02) page 1, lines 7 - 21 page 1, line 34 - page 2, line 2 page 3, lines 6 - 28 page 8, lines 17 - 31 claim 4 figure 1 -----	1-25

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/EP2016/051665

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