(12) UK Patent Application (19) GB (11) 2 355 537 (13) A

(43) Date of A Publication 25.04.2001

(21) Application No 0020919.7

(22) Date of Filing 24.08.2000

(30) Priority Data
(31) 19940551 (32) 26.08.1999 (33) DE

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(51) INT CL^7
G01R 33/385 33/3815

(52) UK CL (Edition S)
G1N NG28 NG38A NG38C N571

(56) Documents Cited
EP 0467558 A1 US 5548653 A US 5446433 A
US 5345177 A US 5129232 A

(58) Field of Search
UK CL (Edition S) G1N NG28 NG38 NG38A NG38C NG42
INT CL^7 G01R 33/3815 33/385
Online: JAPIO, EPODOC, WPI

(54) Abstract Title
MRI device with vibration-isolated cover

(57) A magnetic resonance tomography apparatus comprises a field magnet system 1 and at least one vibration generator 3, which may be the gradient coil system or the cold head if the field magnet is superconducting. An outer cover 2 of the field magnet system which is mechanically connected to the vibration generator contains at least part of an isolation device 6 which prevents the spread of vibrations on at least a partial region of the outer cover. The isolation device may comprise bellows 7 or elastic material, or a stiffening device 8, or piezoelectric actuators.

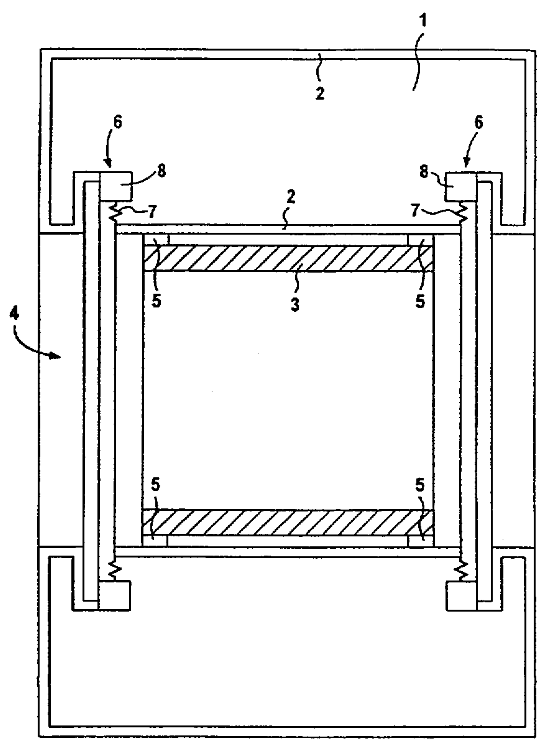

FIG 1

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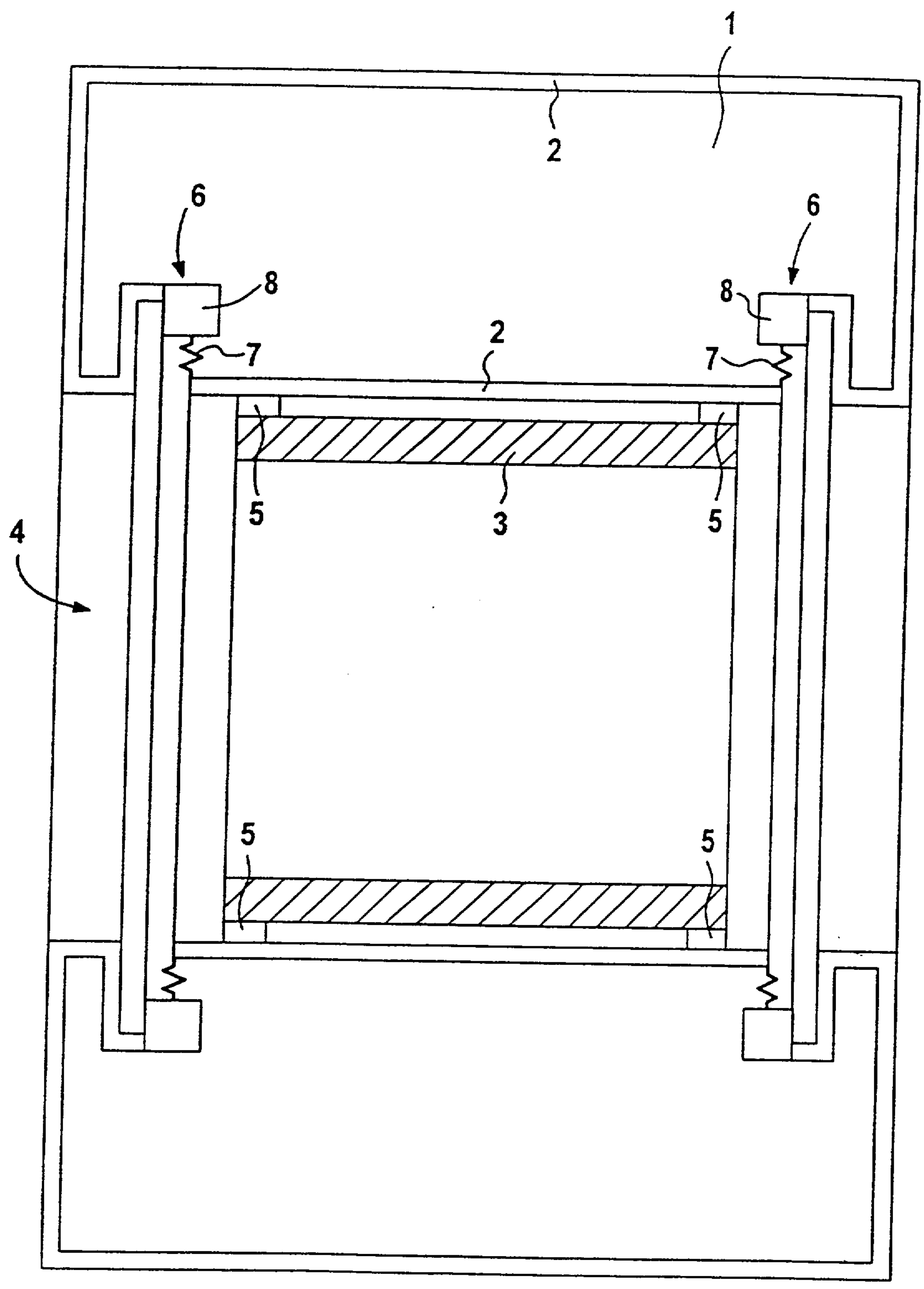

FIG 1

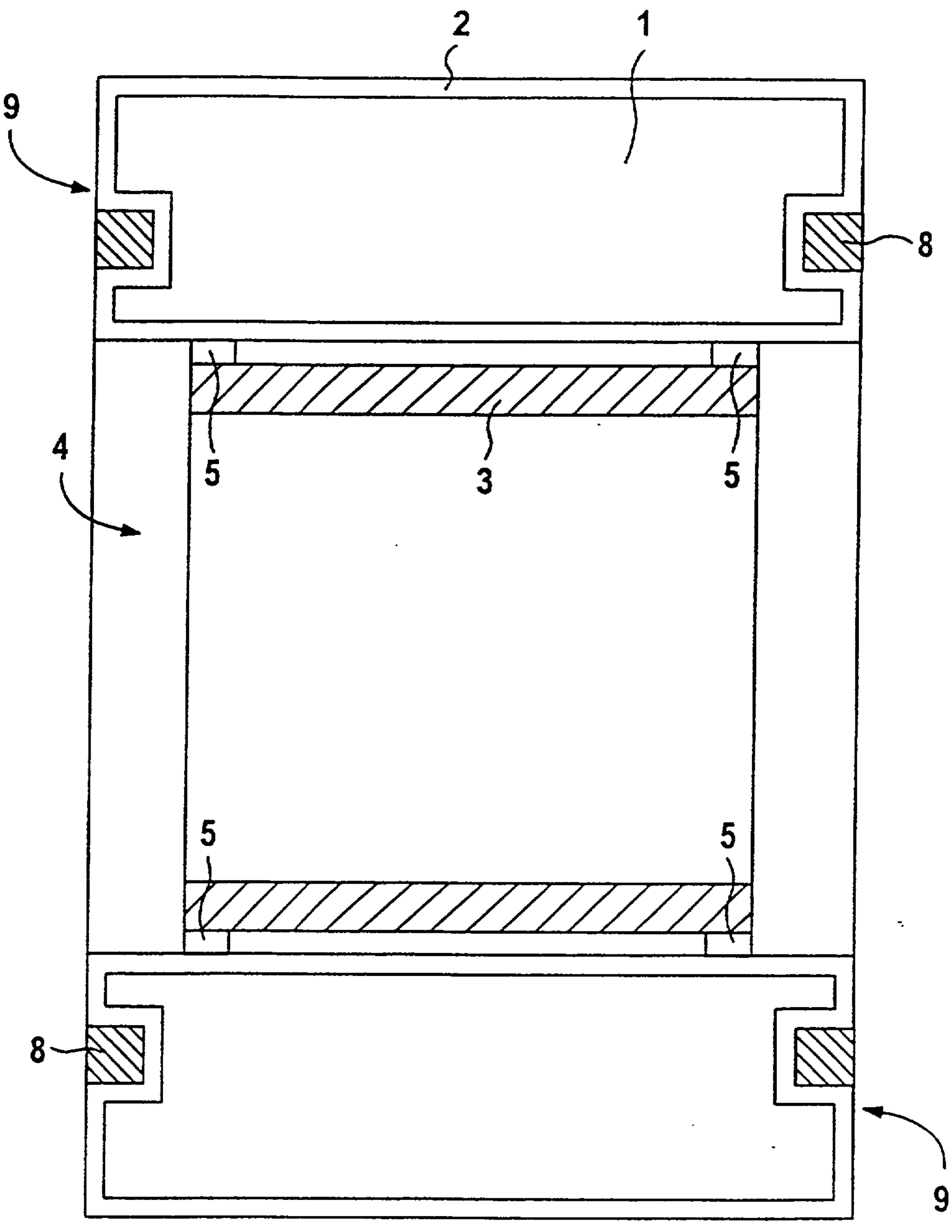

FIG 2

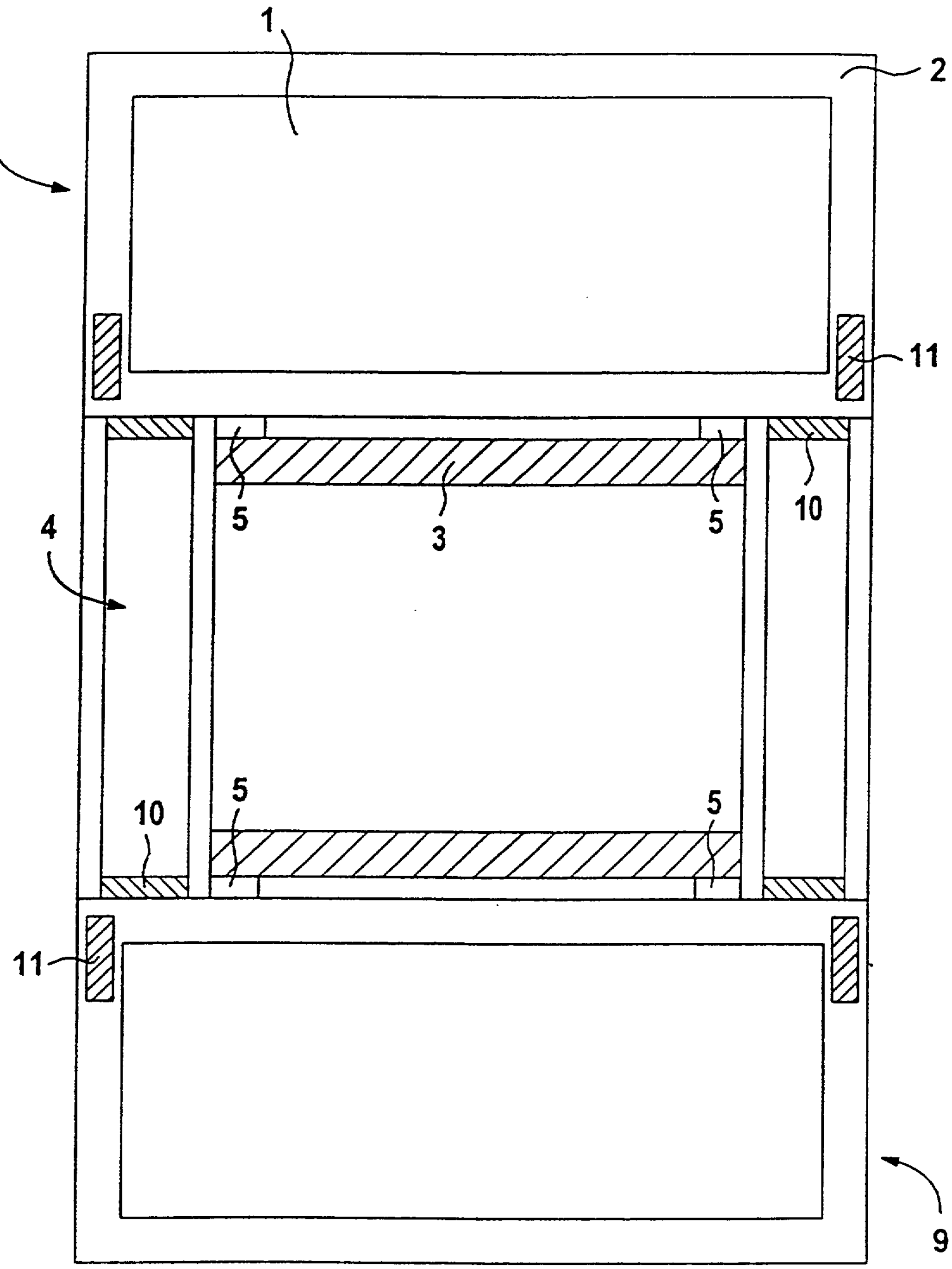

FIG 3

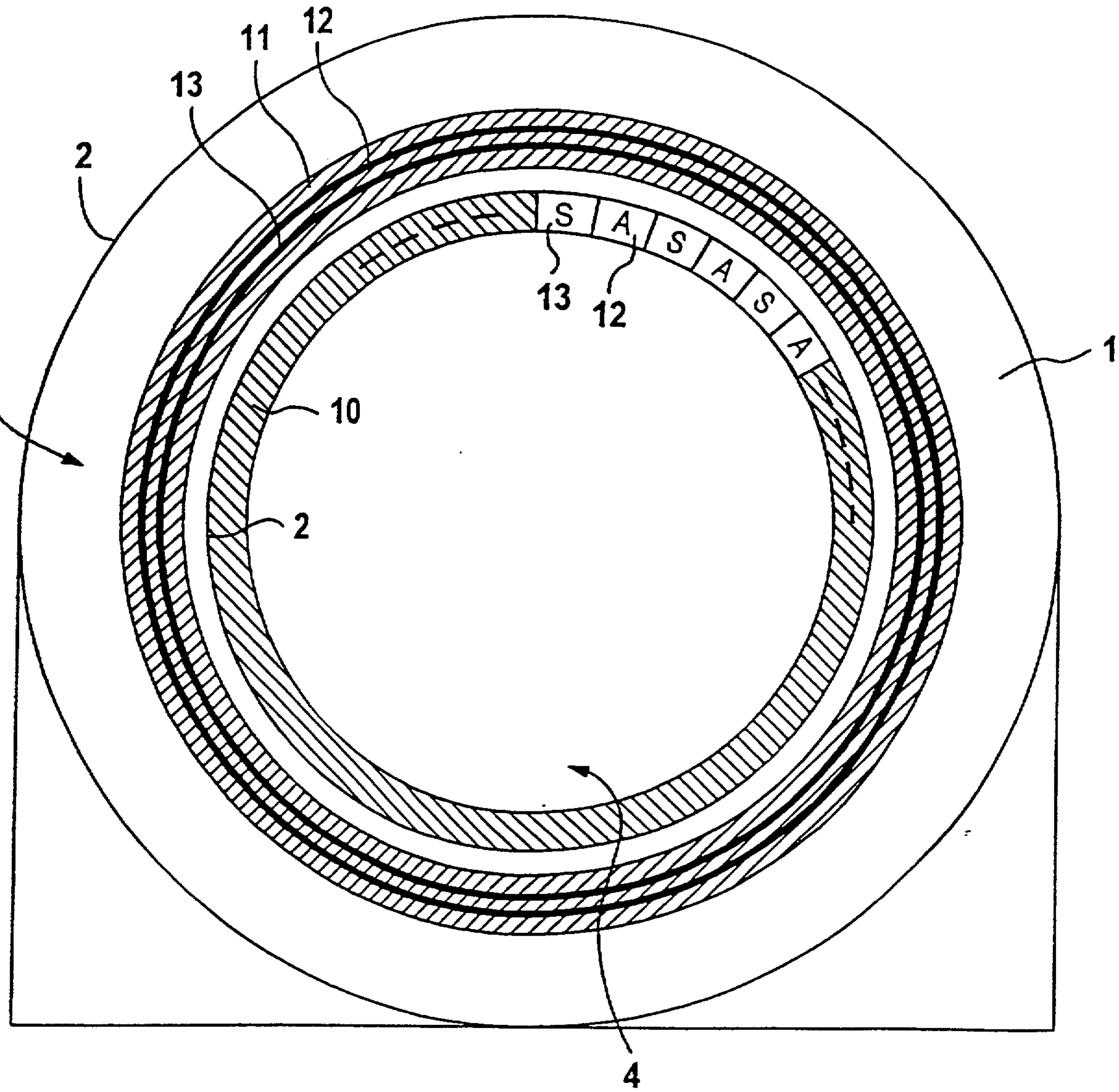

FIG 4

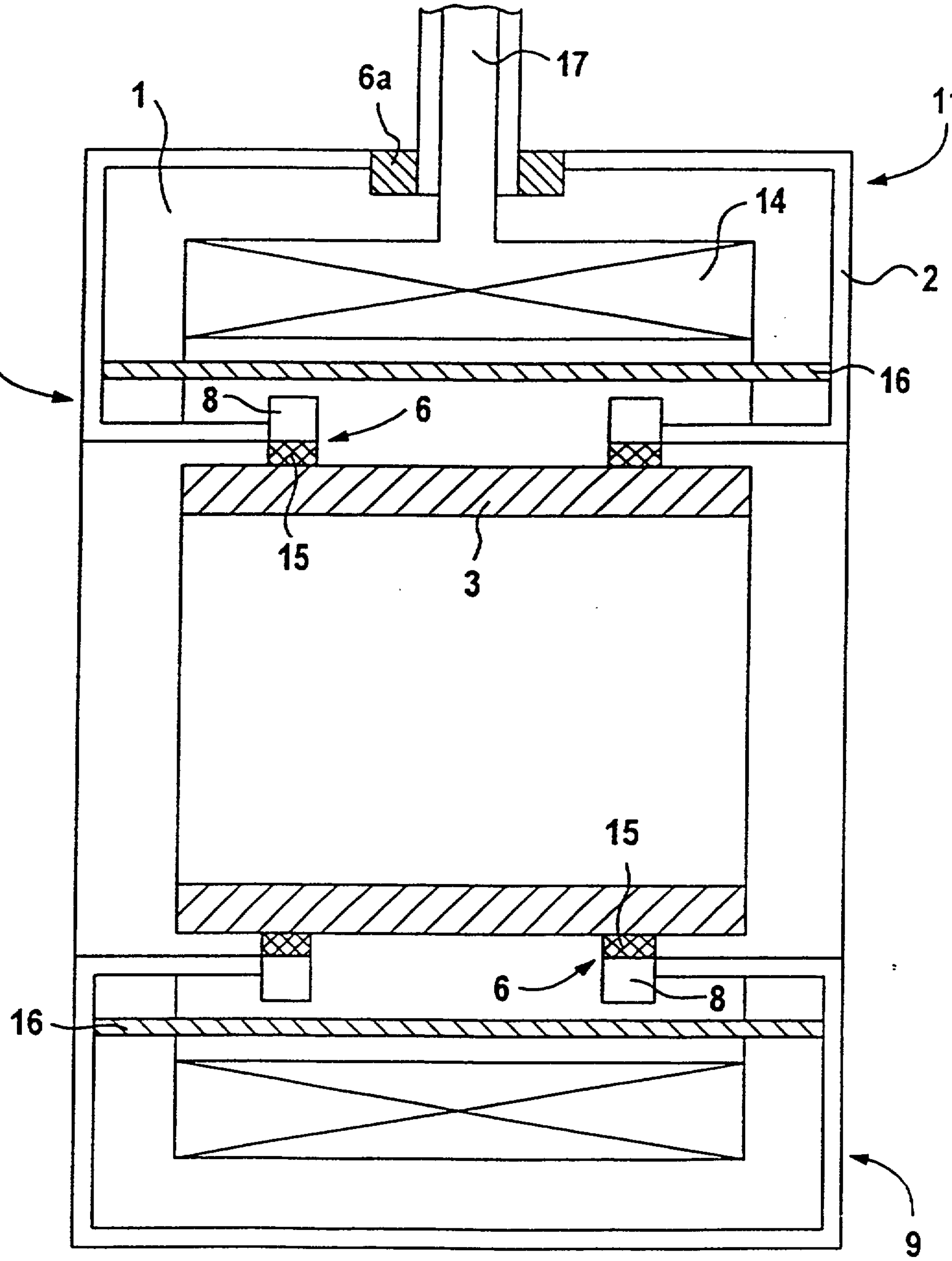

FIG 5

Magnetic resonance tomography device with vibration-isolated outer cover

The invention relates to a magnetic resonance tomography device which contains a base field magnet system and a gradient coil system.

Magnetic resonance tomography is a known technique for producing images of the inside of the body, in particular of a living object of examination. For this purpose, the magnetic resonance tomography device has an area for accommodating the object of examination, a so-called examination area. The examination area is limited spatially at least in part by a surface of the device which surrounds it. In this respect, normally the main part of the aforementioned limiting surface is formed by a surface belonging to the gradient coil system, and a further, normally small part by a part of an outer cover of the base field magnet system. The base field magnet system generates at least in a partial region of the examination area a static base magnetic field which is as homogenous as possible, which the gradient coil system superimposes with rapidly switched magnetic fields with constant gradients, so-called gradient fields, in all three spatial directions. In the process, currents flow in the gradient coils, the amplitudes of which currents reach several 100 A, and which are subject to frequent and rapid changes of current direction with rising and falling rates of several 100 kA/s. These currents are controlled on the basis of pulse sequences and, with an existing base magnetic field of the order of magnitude of 1 tesla, cause vibrations of the gradient coil system as a result of Lorentz forces.

These vibrations are transferred via various spreading paths to the entire surface of the magnetic resonance tomography device. The mechanical vibrations of the various surface regions are translated into sonic vibrations in dependence upon their surface velocity, the sonic vibrations finally causing the known emissions of noise.

The entire surface of a magnetic resonance tomography device comprises substantially the outer cover of the base field magnet system, which forms by far the largest part, and the surface of the gradient coil system including the devices mounted on the gradient coil system such as high-frequency aerials. In this respect, the cover of the base field magnet system is the dominant source (transmitter) of noise irrespective of the measuring point. This also applies to the examination area which is substantially limited by the surface of the gradient coil system.

In the transfer of the vibrations of the gradient coil system to the cover of the base field magnet system one transfer path is dominant. This extends by way of a direct mechanical connection of the gradient coil system with the base field magnet system, for example by way of a keyed (or clamped or wedged) connection of the gradient coil system in a cavity of the base field magnet system.

Further development in the field of magnetic resonance tomography for shortening measuring times and for improving imaging characteristics involves ever faster pulse sequences. These cause an increase of the current amplitudes and the current rising and falling rates in the gradient coils. Without countermeasures, this leads by way of ever greater Lorentz forces and rapid change of the direction of effect of the Lorentz forces by way of ever more violent vibrations to ever greater noise.

Occurrences of noise which are too great can be counteracted, for example, with an increase of the stiffness of the gradient coil system. However, a doubling of the stiffness only brings about an increase of the natural frequencies by about the factor 1.4. Because the gradient coil system is already a very stiff element now, technical and economic limits are placed on increasing stiffness.

In German published patent application DE 195 31 216 A1 a magnetic resonance tomography device is described, the gradient coil system of which is secured to the base field magnet system by way of at least one support, with the support being located in the region of a vibration node of the gradient coil system which is to be expected in operation. In one development the support contains a damper. In this way, disadvantageous effects of vibrations of the gradient coil system, such as acoustic and structural noises and disturbances of image quality, are to be avoided. However, as soon as the gradient coil system has greater stiffness compared with the cover of the base field magnet system, the aforementioned support including the dampers scarcely leads to a clear noise reduction because no effective isolation of the vibration-generating gradient coil system from the outer cover is achieved.

In US 5,345,177 a gradient coil system is described for a magnetic resonance tomography device, which system is mechanically connected to a base field magnet system of the device by way of vibration-damping connection elements. In this arrangement, vibration isolation of the gradient coil system from the base field magnet system takes place in a defined manner within the vibration-damping connection elements. In this way, the entire base field magnet system is to be kept free of vibrations which originate from the gradient coil system. Moreover, in this way vibration and deformation of the operating gradient coil system is to be prevented for noise reduction and high magnetic resonance image quality.

German published patent application DE 44 32 747 A1 describes a basic reduction of vibration of the gradient coil system by way of an active measure. For this purpose, a device, in particular containing piezoelectric components, is arranged in or on the gradient coil system. This device generates forces which counteract the vibrations of the gradient coil system, so that deformation of the gradient coil system is substantially prevented. For this purpose, the piezoelectric components are appropriately controlled by a voltage applied to them. The introduction or fitting of a plurality of piezoelectric components into the gradient coil system, which extends spatially to a comparatively large extent, their voltage supply and their activation are associated with high technical and economic expenditure.

It is therefore desirable to create an economical magnetic resonance tomography device with low noise emissions, which, among other things, reduces the aforementioned disadvantages.

The invention is defined in the independent claim, to which reference should now be made. Further advantageous features are detailed in the dependent claims.

In accordance with preferred embodiments, an outer cover of the base field magnet system, with which the vibration generator is mechanically connected, contains at least a part of an isolation device which prevents spreading of vibrations to at least a partial region of the outer cover, the vibrations being caused by the vibration generator. In this way, vibration of by far the largest part of the surface of the magnetic resonance tomography device may be stopped or reduced to a minimum. The isolation device may prevent in particular a vibrating movement of the cover, which is characterized by a direction of movement perpendicular to the surface of the cover and is therefore particularly relevant with respect to noise. In this way, the dominant source of noise is eliminated or reduced. Because the cover contains the part of the isolation device, the isolation device acts directly at the site of conversion of mechanical vibrations into sonic vibrations which cause noise. An effective location of the isolation device can be determined correspondingly easily. Moreover, the effects of the isolation device on the entire system remain assessable.

In an advantageous development a connection device consists of or contains at least part of the isolation device between the vibration generator and the base field magnet system. Because the connection device is also included as location for the isolation device in addition to the base field magnet system, in particular its outer cover, embodiments may be achieved which save on components and space in a particular manner.

In an advantageous development the isolation device contains a device, preferably constructed as bellows or of elastic material, which acts in a vibration-isolating manner as a result of its mechanical characteristics.

In a further advantageous development the isolation device contains actuators, preferably designed as piezoelectric elements, the spatial extent of which is controlled in such a way that they act in a vibration-isolating manner.

For this purpose, in an advantageous development the isolation device contains sensors, preferably designed as piezoelectric elements, which are arranged in the immediate vicinity of the actuators for vibration detection and control of the actuators. For the precise explanation of the active measure, described above, by means of actuators and sensors for vibration suppression, reference is made to German published patent application DE 44 32 747 A1 already mentioned in the introduction. However, in contrast with the aforementioned text, the plurality of piezoelectric elements is not arranged across a vibration generator which extends spatially to a comparatively large extent, for example a gradient coil system, but piezoelectric elements are arranged in a spatially comparatively small region, for example in the vicinity of a connection between the vibration generator and the base field magnet system. Here they prevent a transfer of vibrations of the vibration generator to the entire cover of the base field magnet system. The economic expenditure for this is accordingly more favourable, with a high noise-reducing effect.

For this purpose, in a particularly advantageous development the actuators or sensors may be small individual parts. For example they may be constructed as small plates and/or fibres and/or films and fitted on the surface of the isolation device and/or integrated into the isolation device. In particular, fitting on the surface, for example on the cover of the base field magnet system, requires only minimal changes of existing components.

In an advantageous development the isolation device contains a stiffening device. An additional use of the stiffening device, in particular in conjunction with an aforementioned development of the isolation device, increases the vibration-isolating effect of the isolation device, in particular between a comparatively stiff vibration generator and a cover which is comparatively soft in contrast. However, even the sole use of the stiffening device also leads to a vibration-isolating effect as a result of vibration reverberations on the stiffening device.

In an advantageous development the vibration generator is a gradient coil system. The gradient coil system of a magnetic resonance tomography device is the main cause of noise, with the result that particular significance must be attached to its isolation.

For this purpose, in an advantageous development the isolation device is arranged in a region in which the cover is not covered (overlaid) by a surface of the gradient coil system which directly faces the cover. In this way, the fact is taken into account that only vibrations of the outer cover of the base field magnet system, which is not covered by surfaces of the gradient coil system, that is to say represents (outer) surfaces of the magnetic resonance tomography device, convert mechanical vibrations into sonic vibrations which cause noise. The vibrations of the covered regions of the cover are of no interest with respect to noise.

In an advantageous development, for this purpose the isolation device is arranged along a closed curve extending on or in the cover, preferably along a closed limit curve between a region in which the cover is covered (overlaid) by the surface of the gradient coil system which directly faces the cover and a region which is not covered. The closed curve may, for example, be annular. In this way it is ensured that the vibration generator is completely vibration-isolated from the remaining device, so that no bridges remain, by way of which the vibration generator can transfer vibrations to the entire cover of the base field magnet system.

The isolation device may be at an least two-part device, with a part preferably being situated on or near the limit of an overlaid region. Such parts may comprise one or more annular elements.

In subclaims 13 to 19 particularly advantageous developments for a magnetic resonance tomography device with a hollow-cylindrical base field magnet system are described, in the cavity of which the gradient coil system is connected by way of the connection device to the base field magnet system.

In an advantageous development, with a cold head of a superconducting base field magnet as vibration generator, the isolation device is arranged along a closed curve in a transition region of the cold head into the base field magnet system. In this way, a transfer of vibration from the cold head to the surface of the remaining device is prevented and the cold head is eliminated as cause of noise.

Further advantages, features and details of the invention are evident from the exemplary embodiments of the invention, described in the following, with reference to the drawings.

Figure 1 shows a longitudinal section of a magnetic resonance tomography device with an isolation device which contains stiffening rings and bellows.

Figure 2 shows a longitudinal section of a magnetic resonance tomography device with stiffening rings.

Figure 3 shows a longitudinal section of a magnetic resonance tomography device with an isolation device which contains actuators and sensors.

Figure 4 shows a cross section of the magnetic resonance tomography device of Figure 3.

Figure 5 shows a longitudinal section of a magnetic resonance tomography device with an isolation device for a cold head.

Figure 1 shows in an embodiment of the invention the longitudinal section of a magnetic resonance tomography device with a hollow-cylindrical base field magnet system 1. The outer cover 2 of the base field magnet system is shown, which forms the surface of the device in the region in which it is not covered by the gradient coil system 3. Within the cavity 4 of the base field magnet system 1 the gradient coil system 3 is connected to the cover 2 of the base field magnet system 1 by way of the connection device 5. So that vibrations of the gradient coil system 3 are not transferred by way of the connection device 5 to the entire outer cover 2, the outer cover 2 contains an isolation device 6 which is divided in two, with each part comprising a set of annular rotating bellows 7 and a stiffening ring 8. In this respect, the isolation device 6 is arranged in the cover 2 in such a way that it is not visible from the outside. In this respect, it is insignificant for the effectiveness of the isolation as to which vibrations are performed by the region of the outer cover 2 which is covered by the gradient coil system 3. The isolation device 6 in particular prevents a transfer of vibrations of the gradient coil system 3 in the circumferential direction. These are particularly relevant with respect to noise. In the direction of the main cylinder axis of the hollow-cylindrical base field magnet system 1 the isolation device 6 is comparatively stiff. In this way, for example, the situation in which vibration of the entire gradient coil system 3 in the direction of the main cylinder axis leads to distortions in magnetic resonance images is prevented.

Figure 2 shows in a further embodiment of the invention the longitudinal section of a magnetic resonance tomography device. Compared with Figure 1, the device has no isolation device 6 in the cover 2 of the cavity 4. Instead, the device in Figure 2 has in the region of the two end faces 9 a respective stiffening ring 8 as isolation device. At the stiffening ring 8 vibrations originating from the gradient coil system 3 are reflected, so that a transfer of vibration to the entire outer cover 2 is prevented. For this purpose, the stiffening ring 8 is securely connected to the cover 2 at as many points as possible. This prevents the cover 2 from vibrating under the stiffening ring 8 and therefore transferring vibrations past the stiffening ring 8. The stiffening ring 8 is made of non-ferromagnetic material of high density, for example non-magnetic steel or lead, in order to achieve a heavy weight and therefore a great noise-reducing effect and to avoid impairments of the magnetic resonance image quality. The heavier the weight of the stiffening ring 8, the greater the vibration-reducing and therefore noise-reducing effect. The larger its contact area with the cover 2, the larger the frequency range for which a vibration-damping takes place. In an advantageous embodiment the cross section of the stiffening ring 8 is not smaller than about five square centimetres. So that the stiffening ring 8 is as inconspicuous as possible from the outside, it is arranged in an appropriate depression of the cover 2.

Figure 3 shows in a further embodiment of the invention the longitudinal section of a magnetic resonance tomography device. Compared with the device in Figure 2, the device in Figure 3 has no stiffening rings 8 at the end faces 9. Instead, the cover 2 has actuators 12 and sensors 13 as isolation device, arranged in annular regions 10 and 11 in or on the cover 2. In the annular regions 10 the actuators 12 and sensors 13 are secured on the surface of the cavity 4 outside the connection devices 5. In the annular regions 11 the actuators 12 and sensors 13 are integrated into the cover 2 at both end faces 9. In this respect, the actuators 12 and sensors 13 are designed, for example, as piezoelectric elements. The actuators 12 and sensors 13 form a regulating circuit. In this respect, the sensors 13 detect occurring vibrations and control the actuators 12 in such a way that the actuators 12 counteract the occurring vibrations by changing their spatial extent. In this way, vibrations of the gradient coil system 3 are not transferred by way of its connection devices 5 to the entire outer cover 2 of the base field magnet system 1.

Figure 4 shows a cross section of the device of Figure 3. In this respect, in the annular region 10 actuators 12 and sensors 13 as small plates and/or films are connected to the cover 2 securely and in a damping-free manner, for example alternately. In the annular region 11 actuators 12 and sensors 13 are integrated into the cover. In this respect, in an advantageous manner the actuators 12 and/or sensors 13 are constructed as fibres.

Figure 5 shows in a further embodiment of the invention a longitudinal section through a magnetic resonance tomography device with a hollow-cylindrical base field magnet system 1 with a superconducting coil arrangement 14. The gradient coil system 3 is connected by way of two rings 15 of elastic material and two stiffening rings 8 to the outer cover 2 of the base field magnet system 1. In this respect, the stiffening rings 8 and the rings 15 of elastic material form an isolation device 6. Moreover, the gradient coil system 3, the isolation device 6 and the outer cover 2 at the same time form a vacuum housing for the superconducting coil arrangement 14. The rings 15 of elastic material act simultaneously as connections between the gradient coil system 3 and the base field magnet system 1. With respect to vibration isolation, the ring 15 of elastic material has similar characteristics to the bellows 7 of Figure 1. In order to compensate for a possible weakening of the structure of the hollow-cylindrical base field magnet system 1 in the direction of the main cylinder axis as a result of a lack of the outer cover 2 between the stiffening rings 8, a longitudinal stiffener 16 is fitted between the end faces 9. The longitudinal stiffener 16 does not have to be constructed to be hollow-cylindrical in a circumferential manner, but an arrangement of several, for example rod-shaped, elements at individual angle positions is sufficient. The magnetic resonance tomography device with superconducting coil arrangement 14 contains a cold head 17 which is used, among other things, for supplying cooling and current to the superconducting coil arrangement 14. To eliminate or dampen a transfer of vibration from the cold head 17 to the cover 2 of the base field magnet system 1, at the transition point of the cold head 17 into the base field magnet system 1 an isolation device 6a is arranged in an annular arrangement between the cold head 17 and the outer cover 2 of the base field magnet system 1.

List of reference numerals

1	base field magnet system
2	outer cover of the base field magnet system
3	gradient coil system
4	cavity of the base field magnet system
5	connection device
6, 6a	isolation device
7	bellows
8	stiffening ring
9	end face
10, 11	annular region
12	actuator
13	sensor
14	superconducting coil
15	ring of elastic material
16	longitudinal stiffener
17	cold head

Claims

1. A magnetic resonance tomography device, containing a base field magnet system, at least one vibration generator, an outer cover of the base field magnet system being mechanically connected to the vibration generator, and an isolation device, wherein the outer cover contains at least a part of the isolation device, which prevents spreading of vibrations caused by the vibration generator on at least a partial region of the outer cover.

2. A magnetic resonance tomography device according to claim 1, wherein a connection device between the vibration generator and the base field magnet system contains a part of the isolation device.

3. A magnetic resonance tomography device according to one of claims 1 or 2, wherein the isolation device contains a device, preferably constructed as bellows or of elastic material, which acts in a vibration-isolating manner as a result of its mechanical characteristics.

4. A magnetic resonance tomography device according to any of claims 1 to 3, wherein the isolation device contains actuators, preferably designed as piezoelectric elements, the spatial extent of which is controlled in such a way that they act in a vibration-isolating manner.

5. A magnetic resonance tomography device according to claim 4, wherein the isolation device contains sensors, preferably designed as piezoelectric elements, which are arranged in the immediate vicinity of the actuators for vibration detection and control of the actuators.

6. A magnetic resonance tomography device according to one of claims 4 or 5, wherein the actuators or sensors are constructed as small plates and/or fibres and/or films.

7. A magnetic resonance tomography device according to any of claims 4 to 6, wherein the actuators or sensors are fitted on a surface of the isolation device and/or integrated into the isolation device.

8. A magnetic resonance tomography device according to any of claims 1 to 7, wherein the isolation device contains a stiffening device.

9. A magnetic resonance tomography device according to any of claims 1 to 8, wherein the vibration generator is a gradient coil system.

10. A magnetic resonance tomography device according to claim 9, wherein the isolation device is arranged in a region in which the cover is not covered by a surface of the gradient coil system.

11. A magnetic resonance tomography device according to any of claims 9 or 10, wherein the isolation device is arranged along a closed curve extending on the cover, preferably along a closed limit curve between a region in which the cover is covered by the surface of the gradient coil system which directly faces the cover and a region which is not covered.

12. A magnetic resonance tomography device according to any of claims 9 to 11, having a hollow-cylindrical base field magnet system, in the cavity of which the gradient coil system is connected to the base field magnet system by way of the connection device.

13. A magnetic resonance tomography device according to claim 12, wherein, with a connection of the gradient coil system by way of at least one left outer and one right outer connection device, the isolation device is arranged in a respective annular region of a cover of the cavity to the left of the left outer and to the right of the right outer connection device, preferably in the vicinity of the connection devices.

14. A magnetic resonance tomography device according to one of claims 12 or 13, wherein the isolation device is arranged in a respective annular region at both end faces of the base field magnet system, preferably in the vicinity of an opening of the cavity.

15. A magnetic resonance tomography device according to any of claims 12 to 14, wherein the isolation device contains the stiffening device in a construction as stiffening ring.

16. A magnetic resonance tomography device according to claim 15, wherein the stiffening ring is constructed with a heavy weight and of non-ferromagnetic material, preferably non-magnetic steel or lead.

17. A magnetic resonance tomography device according to one of claims 15 or 16, wherein the stiffening ring is connected to the base field magnet system, preferably its outer cover, at as many points as possible.

18. A magnetic resonance tomography device according to any of claims 12 to 17, wherein the hollow-cylindrical base field magnet system contains a longitudinal stiffener in the direction of a main hollow cylinder axis.

19. A magnetic resonance tomography device according to any of claims 1 to 18, wherein with a cold head of a superconducting base field magnet as vibration generator, the isolation device is arranged along a closed curve in a transition region of the cold head into the base field magnet system.

20. A magnetic resonance tomography device substantially according to one of the embodiments described herein with reference to the figures.

Application No: GB 0020919.7
Claims searched: 1-20

Examiner: Peter Emerson
Date of search: 12 February 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G1N NG38A, NG38C, NG42, NG38, NG28

Int Cl (Ed.7): G01R 33/3815, 33/385

Other: Online: WPI, JAPIO, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	EP 0467558 A1 (HITACHI) - p3, l 57, 58, fig 1.	1-3, 19
A	US 5548653 A (GEC)	
X	US 5446433 A (GEC) - see collar 54.	1-3, 19
X	US 5345177 A (HITACHI) - see figures.	1-3, 9-12, 14
X	US 5129232 A (GEC) - col 5, l 38-56, figure 3.	1-3, 19

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.