(12) UK Patent Application (19) GB (11) 2 396 698 (13) A

(43) Date of A Publication 30.06.2004

(21) Application No: 0323239.4

(22) Date of Filing: 03.10.2003

(30) Priority Data:
(31) **10246308** (32) **04.10.2002** (33) **DE**

(71) Applicant(s):
Siemens Aktiengesellschaft
(Incorporated in the Federal Republic of Germany)
Wittelsbacherplatz 2, D-80333 München,
Federal Republic of Germany

(72) Inventor(s):
Wolfgang Renz
Johann Schuster
Stefan Stocker

(74) Agent and/or Address for Service:
Haseltine Lake & Co
Imperial House, 15-19 Kingsway,
LONDON, WC2B 6UD, United Kingdom

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

(52) UK CL (Edition W):
G1N NG38C

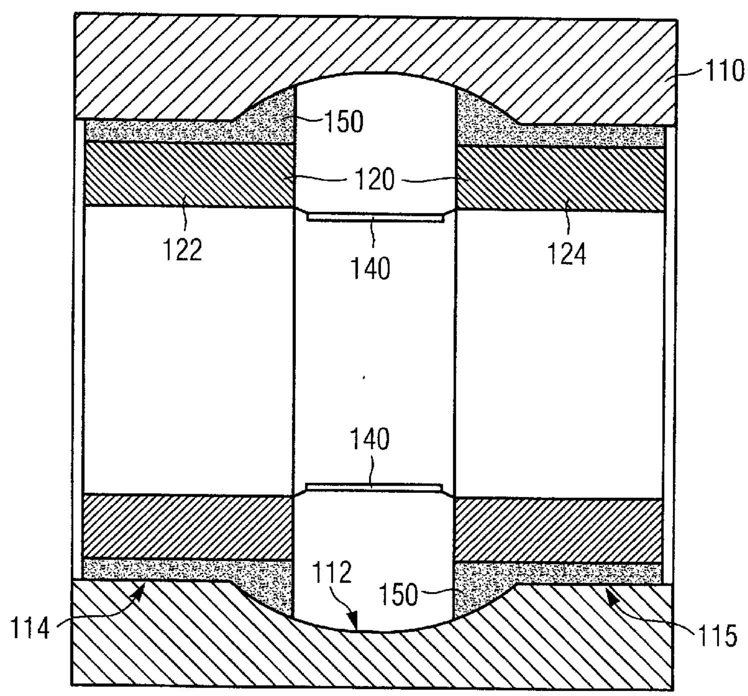
(56) Documents Cited:
US 6075363 B1
US 5630415 A
US 5559435 A
US 5698980 A
US 5570021 A
US 5409558 A

(58) Field of Search:
UK CL (Edition W) **G1N**
INT CL^7 **G01R**
Other: **EPODOC, JAPIO, WPI, INSPEC, IEEE Xplore**

(54) Abstract Title: **MAGNETIC RESONANCE APPARATUS INCORPORATING A GRADIENT COIL SYSTEM**

(57) In a magnetic-resonance apparatus incorporating a gradient-coil system an adhesive has been introduced between the gradient-coil system and the remainder of the magnetic-resonance apparatus for the purpose of securing the gradient-coil system to the remainder of the magnetic-resonance apparatus.

FIG 1



GB 2 396 698 A

FIG 1

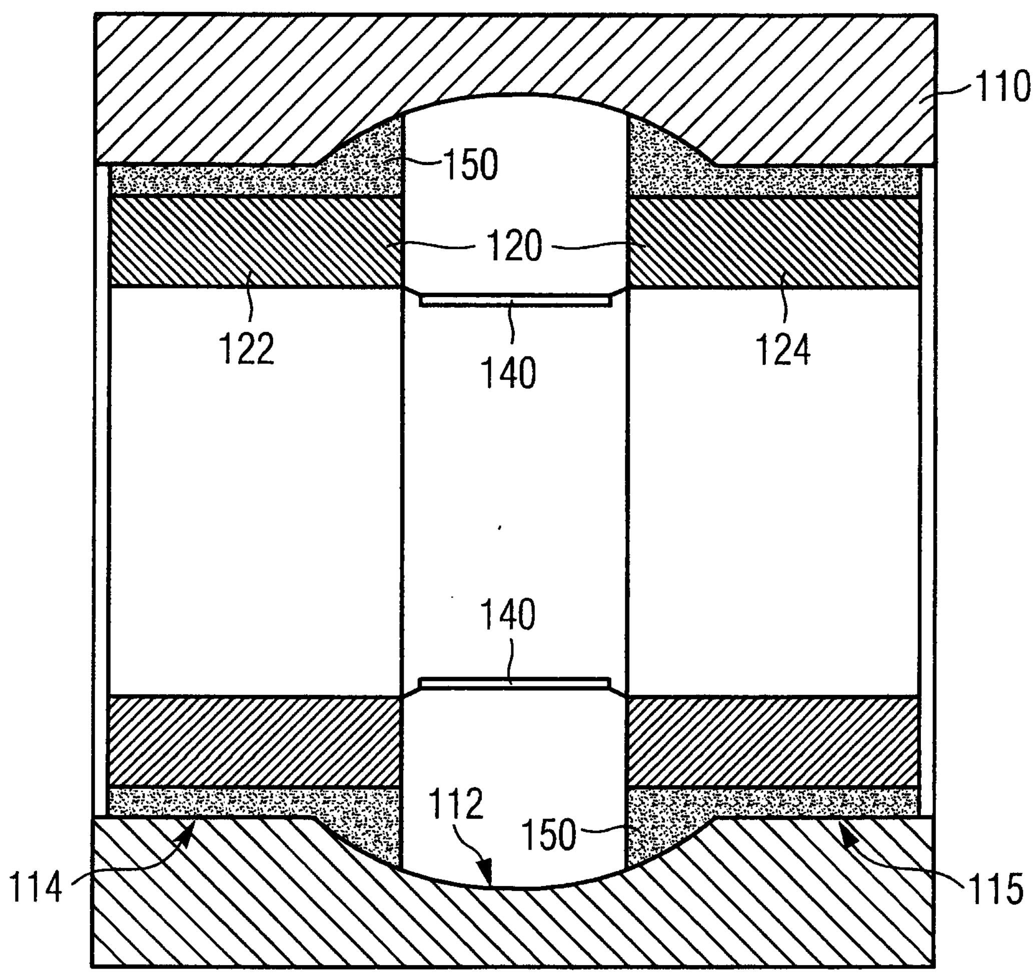


FIG 2

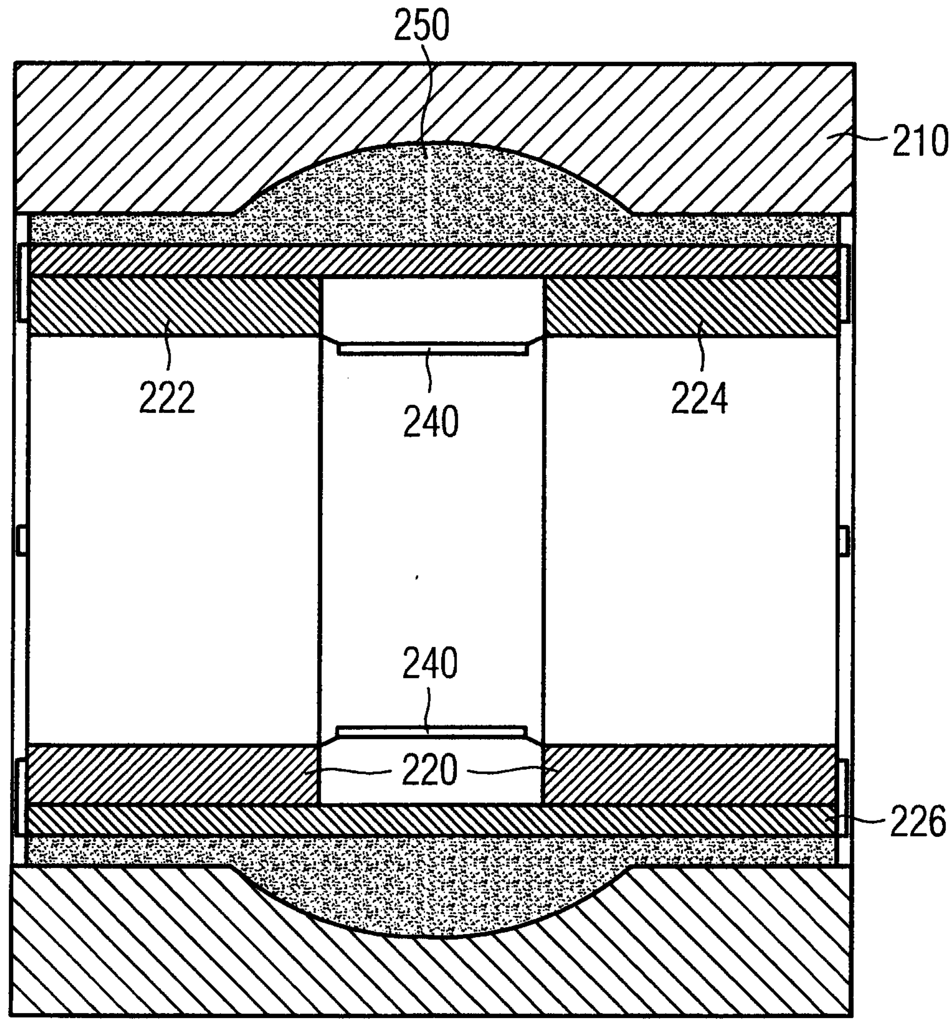
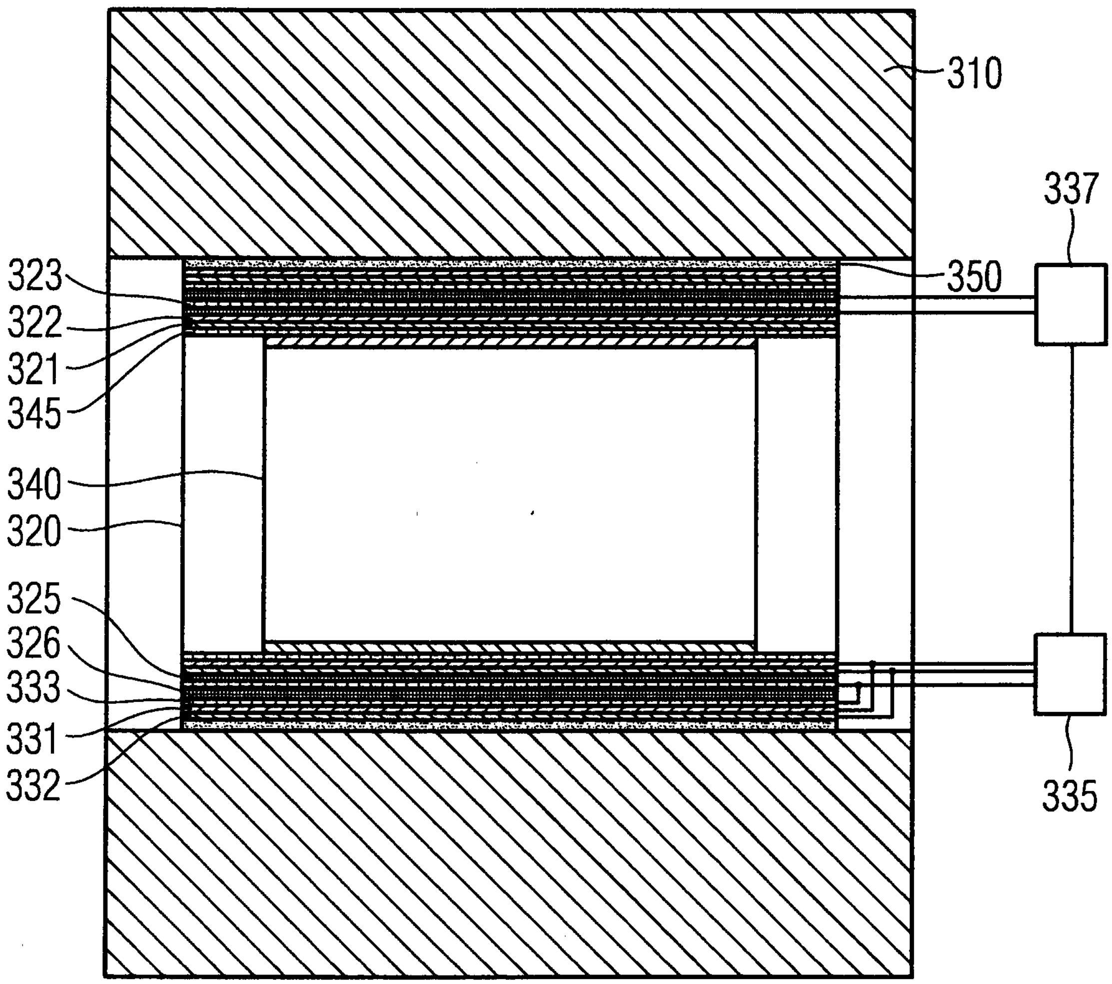


FIG 3



Magnetic-resonance apparatus incorporating a gradient-coil system

The present invention relates to a magnetic-resonance apparatus incorporating a gradient-coil system.

Magnetic-resonance technology is a known technology for, inter alia, obtaining images of the interior of the body of an object under examination. In this connection, rapidly switched gradient fields which are generated by a gradient-coil system are superimposed in a magnetic-resonance apparatus on a static uniform magnetic field which is generated by a main field magnet. The magnetic-resonance apparatus further comprises a high-frequency system which beams high-frequency signals into the object under examination with a view to triggering magnetic-resonance signals and which receives the triggered magnetic-resonance signals, on the basis of which magnetic-resonance images are created.

With a view to generating gradient fields, appropriate currents have to be adjusted in gradient coils of the gradient-coil system. In this connection, the amplitudes of the requisite currents amount to up to several 100 A. The rates of rise and fall of the current amount to up to several 100 kA/s. Given an existing uniform magnetic field in the order of 1 T, Lorentz forces act on these temporally varying currents in the gradient coils, which result in vibrations of the gradient-coil system. These vibrations are passed on to the surface of the magnetic-resonance apparatus via various propagation paths. The mechanical vibrations are converted there into acoustic oscillations which ultimately result in noise, in itself undesirable. Furthermore, the Lorentz forces may also result in a rigid-body motion, which in itself is undesirable, of the gradient-coil system in relation to the remainder of the magnetic-resonance apparatus.

From DE 197 22 481 A1 a magnetic-resonance apparatus is known in which a main field magnet has a first face and a gradient-coil system has a second face, the two faces which are turned towards one another being spaced from one another, and a noise-reducing device for damping the vibrations of the gradient-coil system and/or for reinforcing the gradient-coil system being arranged in contact with the two faces. In one embodiment, the noise-reducing device comprises appropriate seals for the purpose of forming a closed, sealed space between the two faces, said space being filled with sand, foam, a pressurised liquid or other vibration-damping and/or reinforcing substances. In another embodiment, the noise-reducing device comprises several cushions which may be filled with one of the aforementioned substances. In yet another embodiment, in a main field magnet having a cylindrical cavity in which a hollow cylindrical gradient-coil system is arranged, the noise-reducing device is constituted by wedges which are inserted between the two faces.

Furthermore, from DE 101 56 770 A1 a magnetic-resonance apparatus incorporating a gradient-coil system is known in which an electrically conductive structure is arranged and designed in such a way that, at least within an imaging volume of the magnetic-resonance apparatus, a magnetic field of the structure, which is caused by a gradient field via induction effects, is similar to the gradient field. In this case, in one embodiment at least one part of the structure is designed in the form of a cask body as an integral part of a main field magnet. By this means, the gradient-coil system is, inter alia, capable of being designed without screening coils, since the consequences of the switched gradient fields, which are undesirable as such, can be fully controlled by a predistortion by reason of the similarity of the magnetic field that is caused by the structure.

Preferred embodiments of the invention seek to create an improved magnetic-resonance apparatus in which, inter alia, a low emission of noise is advantageously achieved.

According to an embodiment of the invention, there is provided a magnetic-resonance having the features defined by Claim 1. Further advantageous or alternative configurations are described in the dependent claims.

According to a preferred embodiment of the present invention, a magnetic-resonance apparatus incorporating a gradient-coil system is provided, wherein for the purpose of securing the gradient-coil system to the remainder of the magnetic-resonance apparatus an adhesive has been introduced between the gradient-coil system and the remainder of the magnetic-resonance apparatus.

By means of the adhesive, a connection is advantageously created between the remainder of the magnetic-resonance apparatus, as the one point to be joined, and the gradient-coil system, as the other part to be joined. By virtue of surface adhesion and also inner strength, that is to say, by virtue of adhesion and also cohesion, the connection advantageously imparts great rigidity to the bonded unit and hence, inter alia, may enable low-noise operation of the magnetic-resonance apparatus.

In a particularly preferred configuration, the adhesive comprises a material having a low melting-temperature, in particular a wax, such as stearin, paraffin and carnauba wax, with melting-temperatures between 50 °C and 90 °C. As a result, by virtue of a simple control of the temperature of the adhesive, reversible and non-destructive installation and removal of the gradient-coil system may be achieved.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example to the accompanying drawings, in which:

Figure 1 illustrates a longitudinal section through a magnetic-resonance apparatus in which a gradient-coil system comprising two hollow cylindrical halves is secured with the aid of an adhesive in a cavity of a main field magnet having a central region in the form of a cask body;

Figure 2 shows a longitudinal section through a magnetic-resonance apparatus in which a hollow cylindrical support of a gradient-coil system is secured with the aid of an adhesive in a cavity of a main field magnet having a central region in the form of a cask body; and

Figure 3 shows a longitudinal section through a magnetic-resonance apparatus in which a hollow cylindrical gradient-coil system is reversibly secured with the aid of an adhesive in a cylindrical cavity of a main field magnet.

Figure 1 shows, by way of an exemplary embodiment of the invention, a longitudinal section through a magnetic-resonance apparatus. In this case the magnetic-resonance apparatus comprises, for the purpose of generating a static uniform magnetic field, a superconducting main field magnet 110 having a cavity which is bulged in the form of a cask body in a central region 112 and is of cylindrical design in marginal regions 114 and 115 which adjoin both sides of the central region 112. In this connection, the main field magnet 110 is configured, for example, in accordance with DE 101 56 770 A1, which was cited in the introduction. Fitted in the cavity of the main field magnet 110 for the purpose of generating gradient fields is a bipartite gradient-coil system 120 which comprises two hollow cylindrical halves 122 and 124, between which a specially designed antenna system 140 is arranged for the purpose of transmitting high-frequency signals and receiving magnetic-resonance signals. The halves 122 and 124 contain the partial coils of the gradient coils of the gradient-coil system.

Between the outer-casing faces of the two hollow cylindrical halves 122 and 124 and the surface of the main field magnet 110 facing directly towards said faces an adhesive 150 has been introduced which connects the gradient-coil system 120 to the main field magnet 110 by surface adhesion. Adhesives of the most diverse type, for instance also installation foams, can be employed by way of adhesive 150, in which connection both physically hardening adhesives for wet bonding, contact bonding, activation bonding and pressure-sensitive bonding and also chemically hardening adhesives for reaction bonding, comprising chemically curing adhesives, for example a curing resin, are suitable. As a result, the halves 122 and 124 are secured in the main field magnet 110 over a large surface and positively in such a way that, with the rigid installation of the gradient-coil system 120 in the main field magnet 110 which is achieved thereby, a long-life and reliable operation of the magnetic-resonance apparatus is guaranteed, with, at the same time, low emission of noise. In this connection, the installation of the gradient-coil system 120 described in the foregoing, which achieves particularly high rigidity, can be employed with particular advantage in a gradient-coil system that is not actively screened, for example in accordance with the concept corresponding to DE 101 56 770 A1. For, compared to an actively screened gradient-coil system, the comparable gradient-coil system that, by reason of the non-existent screening coils, is not actively screened has, viewed as a whole, lower inherent rigidity, and in the event of approximately equally greater Lorentz forces a greater emission of noise would have to be expected without the countermeasure of the particularly rigid installation in the case of the gradient-coil system that is not actively screened.

Figure 2 shows, by way of a further exemplary embodiment of the invention, a longitudinal section through another magnetic-resonance apparatus. In this case, the magnetic-resonance apparatus comprises a superconducting main field magnet 210 which is configured in accordance with the main field magnet 110 of the magnetic-resonance apparatus of Figure 1. Furthermore, the magnetic-resonance apparatus of Figure 2 comprises a gradient-coil system 220 comprising two hollow cylindrical halves 222 and 224, similar to those of the gradient-coil system 120 of Figure 1.

Corresponding to Figure 1, also in the case of Figure 2 an antenna system 240 is specially designed to be arranged between the two halves 222 and 224.

Otherwise than in the case of Figure 1, however, the two halves 222 and 224 are not directly connected to the main field magnet 210 with the aid of an adhesive; rather, the two halves 222 and 224 are firstly secured to a hollow cylindrical support 226 of the gradient-coil system 220. This support 226 is then secured in the main field magnet 210, in a manner corresponding to that described in connection with Figure 1, by introducing an adhesive 250 between an outer casing of the support 226 and a surface of the main field magnet 210 facing towards said outer casing. Through the use of the mechanically rigidly formed support 226, in the case of the embodiment corresponding to Figure 2 a still more rigid installation of the gradient-coil system 220 is achieved than in the case of the embodiment according to Figure 1, by virtue of which the associated advantages are also further amplified. Compared with the embodiment according to Figure 1, however, the support 226 takes up an additional installation volume.

On the other hand, compared with the gradient-coil system 220 that is secured with adhesive, in the case of a conventional installation of the gradient-coil system 220, for example via the wedges described in the introduction in accordance with DE 197 22 481 A1, vibration of the gradient-coil system 220 with low damping and hence with higher emission of noise would have to be expected, by reason of the gradient-coil system 220 which is constituted in the middle merely by the support 226 and which is therefore mechanically weakened there. Furthermore, in this case the antenna system 240 which is secured between the halves 222 and 224 could be damaged or even destroyed by reason of the greater relative movements of the two halves 222 and 224.

Figure 3 shows, by way of a further exemplary embodiment of the invention, a longitudinal section through another magnetic-resonance apparatus. In this case, a superconducting main field magnet 310 of the magnetic-resonance apparatus is designed with a cylindrical cavity. A substantially hollow cylindrical, casting-resin-potted gradient-coil system 320 is arranged in the cavity. In this case the gradient-coil system 320 comprises, from the inside to the outside, the following hollow cylindrical regions 321 to 333, which are arranged concentrically in relation to one another: a first region 321 comprises a first transverse gradient coil, and a second region 322 comprises a second transverse gradient coil. These transverse gradient coils each comprise four saddle-shaped partial coils. A third region 325 includes a cooling device for cooling the gradient coils. A fourth region 323 includes a longitudinal gradient coil which comprises two solenoid partial coils. A fifth region 326 comprises active and/or passive shim devices and a further cooling device. In a sixth region 333 a screening coil assigned to the longitudinal gradient coil is arranged. A seventh region 331 comprises a further screening coil assigned to the first transverse gradient coil, and an eighth region 332 comprises a further screening coil assigned to the second transverse gradient coil.

With a view to controlling electrical currents in the coils, the latter are connected to a gradient control unit 335, and with a view to controlling a stream of coolant in the cooling devices, the latter are connected to a cooling control unit 337. The screening coils associated with the gradient coils are configured in such a way and capable of being supplied with current in such a way that the magnetic fields that can be generated with the screening coils compensate the magnetic fields that can be generated with the associated gradient coils on a cold shield of the main field magnet 310 at least in such a way that, compared to a gradient-coil system without screening coils, fewer eddy currents are induced in the cold shield by the gradient-coil system 320 which is supplied with current.

With the gradient-coil system 320 which is supplied with current, rapidly switchable magnetic gradient fields can be superimposed on the uniform magnetic field within an imaging volume of the magnetic-resonance apparatus. In order that the switched gradient fields in the imaging volume are not distorted by eddy-current induction and accompanying eddy-current magnetic fields, working proceeds in the gradient control unit 335 with appropriately predistorted control variables for the currents of the gradient coils and associated screening coils.

Furthermore, the magnetic-resonance apparatus comprises an antenna system 340 for the purpose of beaming high-frequency signals into an object under examination which is supported in the imaging volume and also for the purpose of receiving magnetic-resonance signals from the object under examination. In this connection, a high-frequency screen 345 is arranged between the antenna system 340 and the gradient-coil system 320 for the purpose of screening external perturbing influences.

The gradient-coil system 320 is secured in the cavity of the main field magnet 310 in such a way that between an outer cylindrical casing of the gradient-coil system 320 and a surface of the main field magnet 310 facing directly towards said casing an adhesive 350 has been introduced which achieves an appropriate surface adhesion between the faces of both of the aforementioned components of the magnetic-resonance apparatus that face towards one another and which has a melting-temperature approximately between 50 °C and 90 °C. By way of adhesive 350 in this case, use may be made of a wax or a similarly low-melting material. The melting-temperature is determined by the type of wax or the wax mixture that is used, in which connection stearin, paraffin or the somewhat higher-melting, very hard carnauba wax represent suitable types of wax. With a view to establishing the connection between the gradient-coil system 320 and the main field magnet 310, the space between the two aforementioned components of the magnetic-resonance apparatus to be filled with the adhesive 350 is sealed, and the adhesive 350, which has been brought to the liquid state of aggregation by heating, is poured in. For flawless potting, at least the surfaces of the two aforementioned components that directly face towards one another are preheated in the course of potting. After cooling, a planar and permanent connection results between the gradient-coil system 320 and the main field magnet 310.

In normal operation of the magnetic-resonance apparatus, by appropriate adjustments of the gradient control unit 335 and of the cooling control unit 337 it is ensured that a temperature on the outer cylindrical casing of the gradient-coil system 320 is sufficiently distant from the melting-temperature of the wax that is being used. In this connection, the temperature sensors which are arranged in the gradient-coil system 320 in any case can be utilised for the purpose of measuring the temperature. By reason of the comparatively high weight of the casting-resin-potted gradient-coil system 320, in one embodiment a mechanical protection of the gradient-coil system 320 in the cavity of the main field magnet 310 can be employed in addition, for example with wedges in accordance with DE 197 22 481 A1, which was cited in the introduction, in order to prevent a slow possible migration of the wax.

For non-destructive removal of the gradient-coil system 320 from the cavity of the main field magnet 310, the outer casing of the gradient-coil system 320 merely has to be heated to a temperature above the melting-point of the adhesive 350 that is being employed. To this end, the gradient control unit 335 and the cooling control unit 337 are capable of being operated in such a way that, in the case of diminished cooling, corresponding currents in the gradient coils and screening coils are adjusted. In other embodiments, the gradient-coil system 320 is provided with an additional heating device, or the cooling devices and the cooling control unit 337 are designed in such a way that they can be operated with a cooling medium that has been heated beyond the corresponding melting-temperature. As a result of the increase in temperature on the outer casing of the gradient-coil system 320, the adhesive 350 fuses in the region around the outer casing, so that a slidable film arises which additionally facilitates the removal of the gradient-coil system 320. The possibility which was described in the foregoing with reference to Figure 3, namely of being able to install and remove the gradient-coil system 320 in reversible and non-destructive manner, can be employed with advantage in this connection, particularly in the event of an exchange of the gradient-coil system 320, for example in favour of an appropriately higher-powered gradient-coil system and/or in the event of the necessity of removal for repair and/or maintenance work.

List of Reference Symbols

110, 210, 310	main field magnet
112	cask-body-shaped central region
114, 115	cylindrical marginal regions
120, 220, 320	gradient-coil system
122, 124, 222, 224	half of a gradient-coil system
226	support of a gradient-coil system
321, 322, 323, 325, 326, 331, 332, 333	hollow cylindrical region of a gradient-coil system
335	gradient control unit
337	cooling control unit
140, 240, 340	antenna system
345	high-frequency screen
150, 250, 350	adhesive

Claims

1. A magnetic-resonance apparatus having a gradient-coil system, wherein an adhesive is provided between the gradient-coil system and the remainder of the magnetic-resonance apparatus.

2. Magnetic-resonance apparatus according to Claim 1, wherein the adhesive has been introduced between the surfaces of the gradient-coil system and of the remainder of the magnetic-resonance apparatus that face directly towards one another.

3. Magnetic-resonance apparatus according to one of Claims 1 or 2, wherein the remainder of the magnetic-resonance apparatus comprises a cavity in which the gradient-coil system is secured.

4. Magnetic-resonance apparatus according to Claim 3, wherein the cavity is cylindrical.

5. Magnetic-resonance apparatus according to one of Claims 3 or 4, wherein the cavity is bulged in a central region in the form of a cask body.

6. Magnetic-resonance apparatus according to one of Claims 1 to 5, wherein the gradient-coil system comprises two halves which are structurally separate from one another and which contain at least the partial coils of the gradient coils of the gradient-coil system.

7. Magnetic-resonance apparatus according to Claim 6, wherein the halves in the central region of the cavity are secured on both sides of the central region, spaced from one another.

8. Magnetic-resonance apparatus according to one of Claims 6 or 7, wherein the halves are secured within a support of the gradient-coil system, spaced from one another.

9. Magnetic-resonance apparatus according to one of Claims 1 to 8, wherein the gradient-coil system, the halves and/or the support are of hollow cylindrical design.

10. Magnetic-resonance apparatus according to one of Claims 1 to 9, wherein the remainder of the magnetic-resonance apparatus comprises a main field magnet, to which the gradient-coil system is secured.

11. Magnetic-resonance apparatus according to one of Claims 1 to 10, wherein the adhesive comprises a rigid foam or a resin.

12. Magnetic-resonance apparatus according to one of Claims 1 to 11, wherein the adhesive has a low melting-temperature.

13. Magnetic-resonance apparatus according to Claim 12, wherein the melting-temperature lies within a range between 50 °C and 90 °C.

14. Magnetic-resonance apparatus according to one of Claims 1 to 13, wherein the adhesive comprises a wax.

15. Magnetic-resonance apparatus according to Claim 14, wherein the wax comprises stearin, paraffin and/or carnauba wax.

16. Magnetic-resonance apparatus according to one of Claims 12 to 15, wherein for the purpose of controlling currents in gradient coils and/or in screening coils of the gradient-coil system and/or for the purpose of controlling a flow of cooling medium in a cooling device of the gradient-coil system the magnetic-resonance apparatus comprises a control unit which is designed in such a way that in the course of operation of the magnetic-resonance apparatus receiving magnetic-resonance data a temperature of the gradient-coil system on a surface bordering the adhesive is maintained below the melting-temperature by a predeterminable margin.

17. Magnetic-resonance apparatus according to Claim 16, wherein the control unit is designed in such a way that for a release of the fastening of the gradient-coil system the temperature can be adjusted to be greater than or equal to the melting-temperature.

18. A magnetic-resonance apparatus substantially as herein described with reference to the accompanying drawings.

12

Application No:	GB 0323239.4	**Examiner:**	Peter Davies
Claims searched:	1	**Date of search:**	23 April 2004

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1 at least	US 5698980	(SIEMENS) - lines 14 to 26, column 1.
X	1 at least	US 5630415	(CALIFORNIA) - columns 2 (lines 50 to 65) and 4 (line 60) to 5 (line 9)
X	1 at least	US 5559435	(MITSUBISHI) - column 4, lines 56 to 63.
X	1 at least	US 5409558	(TOSHIBA) - figures 7 and 9, colunm 4, lines 16 to 44 and column 5, lines 36 to 44.
A		US 5570021	(G.E.C.)
A		US 6075363	(SIEMENS)

Categories:

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.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[W]:

G1N

Worldwide search of patent documents classified in the following areas of the IPC[7]:

G01R

The following online and other databases have been used in the preparation of this search report:

EPODOC, JAPIO, WPI, INSPEC, IEEE Xplore