

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
20 July 2006 (20.07.2006)

PCT

(10) International Publication Number
WO 2006/075049 A1

(51) International Patent Classification:

G01N 27/90 (2006.01) **G01N 33/30** (2006.01)
G01N 15/00 (2006.01) **G01R 33/12** (2006.01)

(21) International Application Number:

PCT/FI2006/000016

(22) International Filing Date: 13 January 2006 (13.01.2006)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

20050044 14 January 2005 (14.01.2005) FI

(71) Applicant (for all designated States except US): **VALTION TEKNIILLINEN TUTKIMUSKESKUS** [FI/FI];
Vuorimiehentie 3, FI-02150 Espoo (FI).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **ANDERSSON, Peter**
[FI/FI]; Isonmastontie 9 B, FI-00980 Helsinki (FI).

(74) Agent: **BERGGREN OY AB**; Annankatu 42 C, P.O. Box
16, FI-00101 Helsinki (FI).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

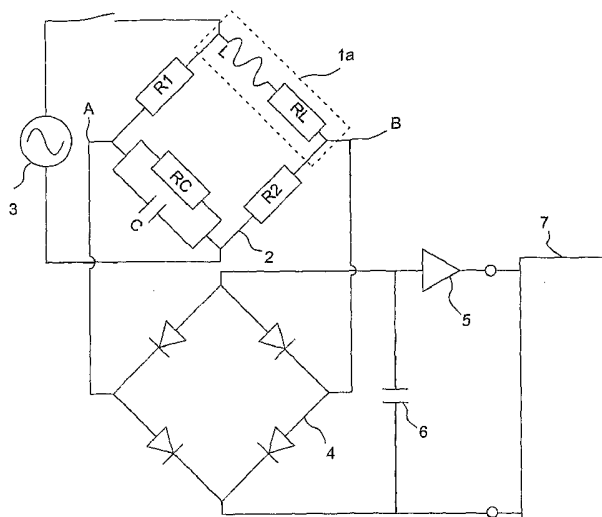
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DEVICE FOR DETERMINING METALLIC CONTAMINANT PARTICLES IN LUBRICATING GREASE



(57) Abstract: This invention relates to a device for determining metallic contaminant particles in lubricating grease. In the device of the invention, a sample is first taken to allow the determination to be made. The device comprises a sensor (1) which comprises a core (1b), on which the measured grease sample is placed, and a sensor coil (1a) which is wound around the core. The device also comprises an alternating current source (3) for supplying the operating voltage. In accordance with the invention the device also comprises an inductance measurement bridge (2) for determining the change of the impedance of the sensor coil (1a), when a sample of lubricating grease containing contaminating particles is applied on the sensor (1), and for outputting a differential output signal to the outputs A and B.

Device for determining metallic contaminant particles in lubricating grease

This invention relates to a device as defined in the preamble of claim 1 for determining the content of metallic contaminant particles in lubricating grease.

- 5 In order to reduce dynamic friction and wear in rotating or axially moving machine parts, for example bearings, these parts are treated with lubricating grease. In the course of time the properties of the lubricating grease deteriorates. This is due to the fact that impurities accumulate from the moving surfaces as they wear in to the grease. These impurities are mainly metallic particles because machines are mainly
10 made out of steel or any other suitable metal. In order to ensure defect free operation, the interfaces of moving parts need to be cleaned and lubricating grease to be replaced at suitable service intervals.

- There are several conventional methods for determining contaminant particles in lubricating grease. One example of these conventional methods is the examination
15 of the lubricant sample with direct microscopy. This as well as other conventional methods are however laborious and slow. They are appropriately performed in laboratory environment and are not practical to perform under field conditions.

There are methods and devices for more easily determining the amount of contaminating particles, especially metallic particles, in lubricating grease.

- 20 In Finnish patent application FI990393, corresponding international application PCT/FI00/00148, a method and a device for determining metallic contaminant particles in lubricating grease is described. According to this method a sample of lubricating grease is subjected to a first magnetic field which is alternating at a constant frequency. This first magnetic field induces eddy currents in the contaminant parti-
25 cles occurring in the sample of lubricating grease. These eddy currents in turn produce a second magnetic field, which influences the first magnetic field by resisting its variations.

- By inductance measurements, the apparent inductance of the coil, resulting from the interference caused by the contaminating particles in the grease sample, can be de-
30 termined.

The device using this method comprises a sampling pole at which the grease sample is placed, and an electric magnet which produces the first magnetic field. In addition

of the first electric magnet the device also comprises a second electric magnet which is used as a reference when the influence of the second magnetic field produced by the eddy currents induced in the sample are determined. This second electric magnet is identical to the first electric magnet and is preferably supplied from
5 the same alternating current source as the first electric magnet. In addition to these the device also comprises a measuring unit comprising a comparator and a amplifier.

Because this previously known device uses a second electric magnet as a reference for inductance measurements, the device needs non-standard, expensive and large
10 sized components. Also the use of a second electric magnet as a reference increases the power consumption of the device because of the resistive losses of the coil.

The object of the invention is to overcome the drawbacks related to the device described above. Another object of the invention is to provide a new smaller, less expensive, and less power consuming device for determining the content of contaminating particles, especially metal particles, in a lubricating grease.
15

The device of the invention is characterized by the features defined in claim 1. The dependent claims set forth preferred embodiments of the invention.

In the device of the invention, a sample is first taken to allow the determination to be made. The device comprises a sensor which comprises a core, on which the measured grease sample is placed, and a sensor coil which is wound around the
20 core. The device also comprises an alternating current source for supplying the operating voltage. In accordance with the invention the device also comprises an inductance measurement bridge for determining the change of the impedance of the sensor coil, when a sample of lubricating grease containing contaminating particles
25 is applied on the sensor, and for outputting a differential output signal to the outputs.

In the preferred embodiment of the invention the sensor coil is a part of the inductance measurement bridge. The device may also contain a rectifier bridge and a filter capacitor for rectifying and filtering the output signal from the measurement
30 bridge.

The invention has the advantage of the device being smaller sized and using less power. Another advantage of the inventions is that that the inexpensive mass produced passive components can be used instead of a comparison amplifier and a reference coil.

The invention will be explained in detail below with reference to the accompanying drawing, in which

- figure 1 is a schematic view of the electric circuit of the device of the invention;
figure 2 is a view of the sensor of the device of the invention;
5 figure 3 is a schematic view of one user interface circuit of the invention;
figure 4 is a schematic view of another user interface circuit of the invention;
figure 5 is a schematic view of yet another user interface circuit of the invention;
and
figure 6 is a presentation of the voltage vectors of the circuit of the invention.

- 10 The device of the invention utilizes the theoretical data of the method described in the Finnish patent application FI990393. A variation in the impedance of the sensor coil 1a can be measured by electric means. This is preferably carried out as follows:

The device of the invention presented in figure 1 preferably comprises a sensor coil 1a, a measurement bridge 2 and an alternating current source 3. The sensor coil 1a
15 is part of sensor 1, which has an electric magnet comprising a coil 1a wound around a core 1b as presented in figure 2. The measurement bridge 2 used for the determination of the impedance of the sensor coil is preferably a traditional Maxwell-Wien bridge.

The measurement bridge is operated from an alternating current source 3. The alternating current has stabilized mean-effective-value, frequency and wave form. Due
20 to the positive phase shift caused by the inductance L of the sensor coil 1a, the wave of the alternating electric current at the output terminal B of the measurement bridge 2 will be behind the wave of the alternating voltage supplied to the measurement bridge 2 by the alternating current source 3.

25 The amplitude and phase shift of the output B of the measurement bridge 2 with respect to the operating voltage is defined by the sensor coil 1a ($L+RL$) and serial resistance $R2$. On the opposite side of the measurement bridge 2 the capacitor C and its parallel resistor RC are chosen to outbalance the positive phase shift caused by the inductance of the sensor coil 1a. They have a negative phase shift so that the alternating current will be ahead of voltage of alternating current source 3. These can
30 be seen from the voltage vectors presented in figure 6.

The amplitude and phase shift of the output A of the measurement bridge 2 with respect to the operating voltage is defined by the capacitor C , parallel resistance RC and serial resistor $R1$. If the capacitor C and the resistors RC and $R1$ are chosen ac-

According to the sensor coil 1a, the amplitudes and the phase shifts at both outputs A and B can be fixed to an appropriate basic level that gives a low basic output signal from the measurement bridge 2. That is the potentials at both outputs A and B are equal when the sensor coil 1a is outbalanced.

- 5 The polarity of the basic output signal from the measurement bridge 2 must be the same as in a measurement situation. In a measurement situation, the amplitude and the phase shift at the output B changes with an increase in the apparent inductance of the sensor coil 1a when a grease sample having an amount of metal contaminating particles is placed on the core 1b, causing a potential difference between the two
10 outputs (A-B). This increases the root-mean-square value of the output signal.

The output signal from the outputs A and B is then rectified in a rectifier bridge 4. A filtering capacitor 6 is supplied for filtering the resulting DC current. The rectified and filtered signal can then be analyzed and the result of the analyze outputted to the user with one of the several possible types of arrangements in an user inter-
15 face circuit 7.

The simplest example of the user interface circuit 7 is a qualitative threshold display. For example a LED 9 in figure 3 can be illuminated when the voltage of the output signal exceeds a pre-set level. There can be several levels each level lighting a different colored LED 9. At the same time an audible alarm can be heard. The
20 alarm level is adjusted by means of a variable resistor 8 when a calibration grease with a specific metal particle content is applied to the sensor coil 1a.

Another example of the user interface circuit 7 is a quantitative display. This display can be a digital voltage displaying device 11 with an A/D-converter 10 as presented in figure 4, or a traditional coil instrument, or some other type of device capable of displaying voltage signal levels. It indicates the metal particle content as a
25 number that is relative to the apparent change in the inductance of a sensor coil 1a. It however does not express the metal particle content as such; the value can be compared with a given limit value for acceptable grease samples, or the value can be externally converted into a metal particle content by using a library of data obtained by previous or subsequent measurements on grease samples of known metal
30 particle content.

The third example of the user interface circuit 7 is an analytical equipment, which by means of software converts each measurement signal into a metal particle content. This equipment can for example be a microcontroller 13 having an A/D-

converter input 12 as presented in figure 5. The result of the measurement is then displayed for example on a digital display 14. This equipment has to be calibrated by using grease samples of known metal particle content. In this calibration process a conversion table between voltage levels and metal particle contents is created and
5 saved to be used by the software during measurements. This analyzer circuit has the advantage that the software can collect several measurement results and save them to a data file for later inspection.

If the rectified and filtered output signal is too weak before analyzing, an amplifier can be added to the circuit before user interface circuit.

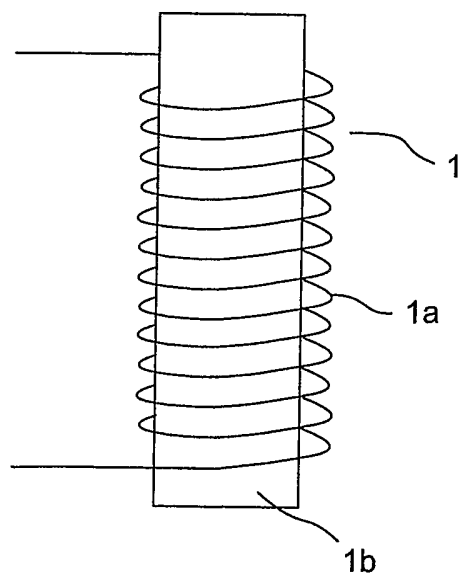
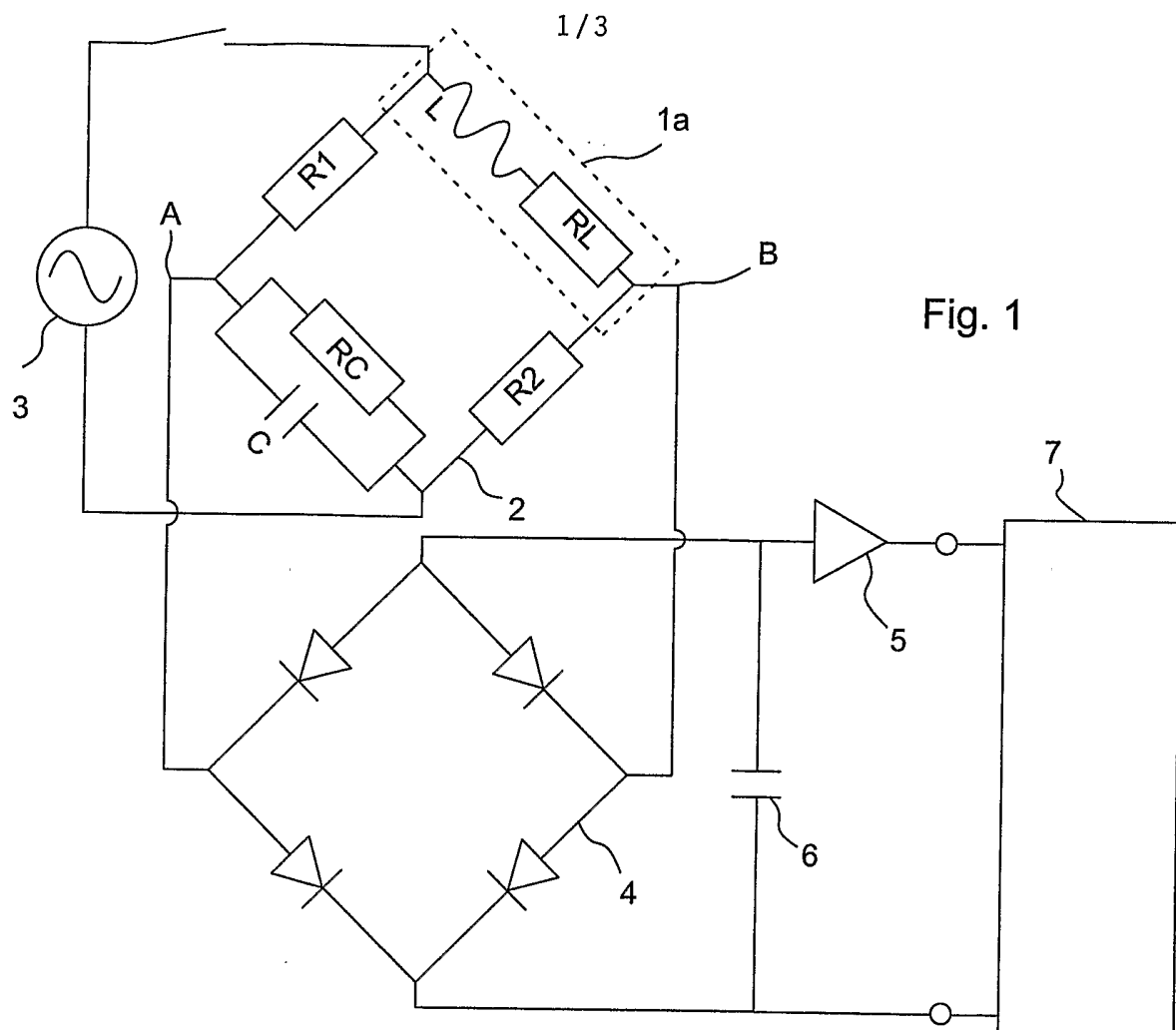
10 In order to reduce any thermal effects on the grease sample, and its softening due to this, the sensor coil 1a can be de-connected from the measurement bridge 2 between measurements. This also reduces further the power consumption of the measuring device, especially in portable devices.

For the one skilled in the art it is obvious that the preceding example does not limit
15 the scope of the invention, and that the different alternatives of the invention are defined by the claims.

What is Claimed is:

1. A device for determining metallic contaminant particles in lubricating grease, a sample being taken for determination, the device comprising:
 - a sensor (1) comprising a core (1b), on which the measured grease sample is placed, and a sensor coil (1a) wound around the core (1b); and
 - an alternating current source (3) for supplying the operating voltage;
- characterized** in that, the device further comprises:
 - an inductance measurement bridge (2) for determining the change of the impedance of the sensor coil (1a), when a sample of lubricating grease containing contaminating particles is applied on the sensor (1), and outputting a differential output signal to the outputs (A and B).
2. A device for determining metallic contaminant particles in lubricating grease according to claim 1, **characterized** in that, the sensor coil (1a) is a part of the inductance measurement bridge (2) on one side, and the capacitor (C) and parallel resistor (RC) are part of the inductance measurement bridge (2) on the opposite side.
3. A device for determining metallic contaminant particles in lubricating grease according to claim 1 or 2, **characterized** in that, the device further contains a rectifier bridge (4) and a filter capacitor (6) for rectifying and filtering the output signal from the measurement bridge (2).
4. A device for determining metallic contaminant particles in lubricating grease according to claims 1, 2 or 3, **characterized** in that, the device further comprises an amplifier (5) for amplifying the rectified and filtered output signal.
5. A device for determining metallic contaminant particles in lubricating grease according to any of claims 1-4, **characterized** in that, the device further comprises an user interface circuit (7) for analyzing the rectified and filtered output signal and outputting the result to the user.
6. A device for determining metallic contaminant particles in lubricating grease according to claim 5, **characterized** in that, the user interface circuit (7) is a qualitative threshold display.

7. A device for determining metallic contaminant particles in lubricating grease according to claim 5, **characterized** in that, the user interface circuit (7) is a quantitative display.
8. A device for determining metallic contaminant particles in lubricating grease according to claim 5, **characterized** in that, the user interface circuit (7) is an analytical equipment.



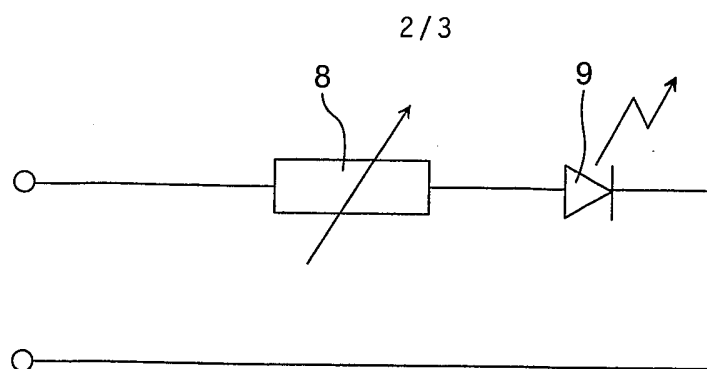


Fig. 3

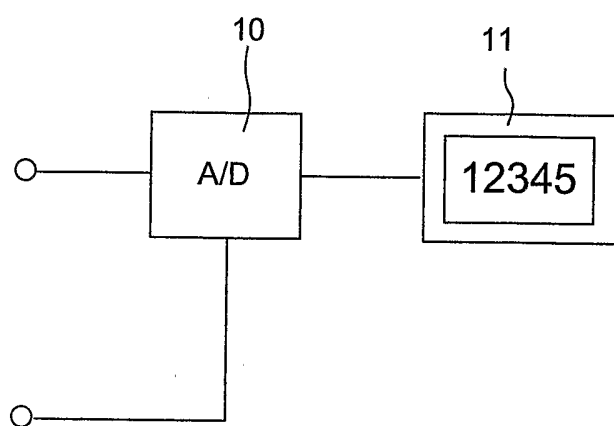


Fig. 4

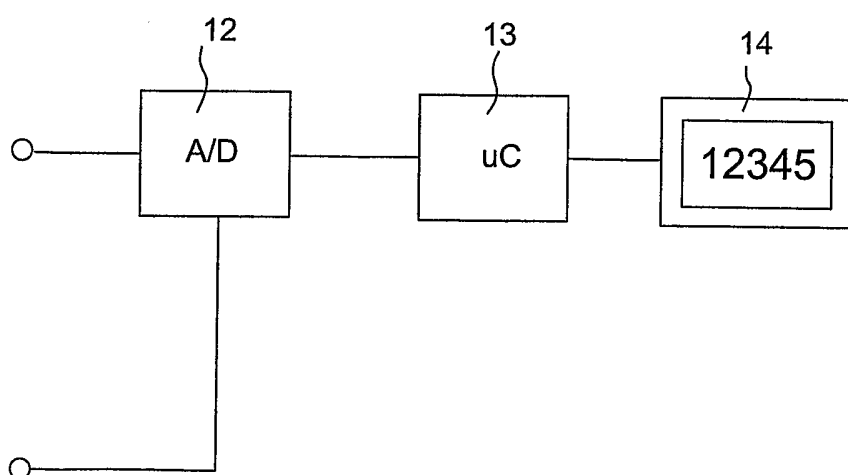


Fig. 5

3 / 3



Operating voltage $u_{RES1} = u_{RES2}$

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2006/000016

A. CLASSIFICATION OF SUBJECT MATTER		
See extra sheet		
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)		
IPC8: G01N, G01R		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
FI, SE, NO, DK		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPO-internal, WPI		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	JP 6331600 A (NEW COSMOS ELECTRIC CO) 02 December 1994 (02.12.1994)	
X	abstract, fig. 1, English translation paragraphs 1, 7, 13	1, 2
Y	abstract, fig. 1, English translation paragraphs 1, 7, 13	3-8
Y	US 4731578 A (TSAPRAZIS EDWARD) 15 March 1988 (15.03.1988), abstract, column 3, lines 19-52, column 4, lines 51-62, fig. 2	3-8
A	WO 0050883 A1 (VALTION TEKNILLINEN et al.) 31 August 2000 (31.08.2000), cited in the application	1-8
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
10 March 2006 (10.03.2006)		10 April 2006 (10.04.2006)
Name and mailing address of the ISA/FI National Board of Patents and Registration of Finland P.O. Box 1160, FI-00101 HELSINKI, Finland Facsimile No. +358 9 6939 5328		Authorized officer Rauli Erävalo Telephone No. +358 9 6939 500

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2006/000016

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
JP 6331600 A	02/12/1994	None	
.....			
US 4731578 A	15/03/1988	GB 2219405 A	06/12/1989
		US 4878019 A	31/10/1989
		FR 2581455 A1	07/11/1986
		IT 1191878 B	23/03/1988
		DE 3612573 A1	06/11/1986
		JP 61253455 A	11/11/1986
		GB 2175092 A	19/11/1986
.....			
WO 0050883 A1	31/08/2000	AU 2918300 A	14/09/2000
.....			

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.

G01N 27/90 (2006.01)**G01N 15/00** (2006.01)**G01N 33/30** (2006.01)**G01R 33/12** (2006.01)**G01R 27/26** (2006.01)