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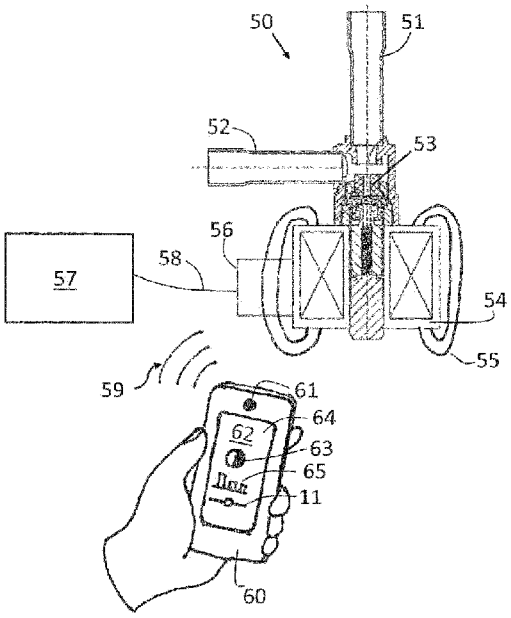


Fig. 7

(57) Abstract: An app for testing the presence or not of a direct current magnetic field generated by an electronic or electrotechnical device under test is disclosed. Service technicians increasingly use smartphones as aide in installation, maintenance and troubleshooting and the indication of the existence of a magnetic field or not is a helpful information to the service technician. Using a sensor in the smartphone the measurement of weak magnetic fields generated by direct current devices has proved problematic. A solution to this problem is that a direct current magnetic field detection limit (DC_{lim}) is set in the app, and that the presence of a magnetic field potentially generated by said device is only indicated on the smartphone screen if the measured direct current magnetic field (DC_{meas}) is larger than the set magnetic field detection limit (DC_{lim}). The invention further concerns a method for calibrating an app for the measurement of weak direct current generated magnetic fields.

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AN APP USED IN A SMARTPHONE FOR DETECTING MAGNETIC FIELDS OF INDUSTRIAL PRODUCTS

FIELD OF THE INVENTION

The present invention relates to a software service tool implemented in a handheld communication device, such as a smartphone. A software application – an app – is used for servicing particularly industrial electronic or electromechanical products by measuring their magnetic fields. The invention also relates to a method for calibrating the smartphone app.

BACKGROUND OF THE INVENTION

In a constantly increasing pace the smartphone becomes a more and more ubiquitous tool, also in the area of maintenance and service of industrial products. Service technicians today use the smartphone as a service tool as frequently as, e.g., the classical multimeter. The service technician – either as installer, maintainer or repair man – uses the smartphone as installation or repair guide, or more recently also as a measurement tool. Smartphones of today have a large number of sensors built in, such as temperature, humidity and acceleration sensors. The applicant of the current patent application has recently promoted an app tool for measuring the magnetic field of electronic or electromagnetic devices, especially in the industrial area. A great help for the service technician during trouble shooting is the fast indication of whether the windings in the stator of the electrical motor or the coil of a solenoid valve are conducting electrical current. In case of an installed solenoid valve, where the plunger does not move, it is not immediately evident if the error is caused by a broken coil or a mechanical jamming inside the valve or in the pipe. The smartphone incorporating the app tool promoted by the applicant is placed in the proximity of the electrically energized product under test, and if sensing a rotating magnetic field it displays a graphical animation on the screen of the smartphone, indicating that the coil is ok.

The app described above works well with alternating current magnetic fields which generate a significant and identifiable signal, but in cases where the motor or the solenoid valve is supplied with direct current, the magnetic field generated can be small and succumbs to the influence of outside magnetic stray fields, which are especially present in industrial environments. A further complicating factor is that the quality of

magnetic field sensors in smartphones vary from one manufacturer to another, hence the magnetic app tool may function on one type of smartphone, but not on another. Based on the foregoing problems, the current invention sets out to describe an app service tool for measuring also weak magnetic fields, and which reliably can detect such fields irrespective of the company origin of the smartphone.

DESCRIPTION OF THE INVENTION

The invention resides in adjusting the measurement sensitivity of the app in relation to the background magnetic field level. The inventive app is intended for use in a smartphone which comprises a magnetic field sensor, and the app displays on a screen of the smartphone the presence or not of a magnetic field generated by the electronic device, being measured by the magnetic field sensor. A direct (DC) or an alternating (AC) current magnetic field detection limit (DC_{lim}, AC_{lim}) is set in a calibration step while measuring, i.e. the limit is adjusted in the app manually or automatically, and the presence or not of a magnetic field, potentially generated by said device under test, is only indicated on the smartphone screen if the measured DC or AC current magnetic field is larger than the set magnetic field detection limit (DC_{lim}). The technical effect of this design is, that the measuring app is calibrated dynamically on location when measuring the DC or AC current magnetic field generated by the electronic device under test, and hence compensates for differences in sensor signal level of smartphones from different manufacturers.

The magnetic field detection limit is adapted to match the device under test in front of the smartphone's sensor, hereby reducing the number of incidents where the DC or AC current magnetic field measured on the device is over-amplified by the sensor and its electronics, thus not detectable by the app. The app will only indicate the presence of a magnetic field from the device if the measured magnetic level surpasses the set DC or AC current magnetic detection limit. This is done by the app in a programmed comparison between the measured magnetic field value and the set magnetic field value. In this way the app is brought to work within an active measuring area instead of working in an over-amplified area. Although there may be occasions where the direct current or alternating current magnetic signal is too weak to be measured - the signal to noise ratio too small – setting an adaptive limit will increase the number of measurement successes.

The set magnetic field detection limit is selected to be at a level that will compensate for undesired magnet field radiation into the sensor, such as the magnetic field from the earth, the undesired magnetic fields from the smartphone itself, namely its radio antennas, power sources and electronic power circuits, and also compensate for other magnetic fields categorized as background noise. The set magnetic field detection limit will also reduce the effect of signal over-amplification by the uncalibrated sensor and electronic circuitry. If the detection is positive, the app will display a graphic indicative of the presence of a DC or an AC magnetic field. If negative, the app will display a graphic indicating non-presence of the magnetic field. The term "app" is here used in its general day-to-day meaning, i.e. a software program used in a smartphone and interfacing with a user.

In one embodiment of the inventive app, the magnetic field detection limit is set in the calibration step by a human user of the app, said human user adjusting a sensitivity scale displayed in the app on the screen of the smart phone. This is an advantageous solution because it compensates for differences in measurement accuracy from one smartphone make to another.

Our tests have shown that iOS based smartphones tend to have high resolution sensors, that are also calibrated. On the other hand, however, we frequently encounter Android smartphones with a too low or a too high magnetic field sensitivity, making the detection window of the app too narrow. Some smartphones have two magnetic field sensors, others only one, and this contributes to the complexity. These differences can be compensated for by letting the service technician, by hand, adjusting a slider on the screen until a signal is detected or is undetected. Preferably the slider is placed just at the limit of detection and un-detection. At this limit the above-mentioned magnetic background levels are more or less compensated for, as is the contribution from varying sensor amplifications. Measurement can then begin. Instead of adjusting a graphic, slider the user can also adjust the volume up and down buttons placed on the chassis of the phone. The manual adjustment of the magnetic field detection limit is particularly advantageous if a larger number of devices are under test in the same location. Once the calibration described above has been done, the undesired impact of both background magnetic field noise and the short comings of an uncalibrated sensor has been removed, and repeated measurements can begin without having to calibrate the app again.

In another embodiment of the invention, the magnetic field detection limit is set automatically in the calibration step by the app itself based on measurements by the

sensor. In this case the app calibrates itself, which is a particularly user-friendly way to ensure a measurement of a DC or AC current magnetic field. The app of the smartphone automatically adapts to the magnetic level of the surroundings, taking background levels and differences in sensor signal amplification into account. This adaptation can be made fully automatic, triggered by the program of the app, or semi-automatic by the service technician pressing a button on the screen of the smartphone, hereby activating the app and its automated magnetic level finding. The magnetic field detection limit may be set automatically in the app by letting the app adjust the amplification of the sensor signal fed to the app until a borderline between a detected sensor signal and a no-signal is reached. This value is then selected as the magnetic field detection limit. Thus, the threshold is placed just at the limit of detection and un-detection of the signal from the sensor. The automatic setting of the magnetic field detection limit can also be made by an algorithm that stores the results from earlier manual limit settings, and then, after a period of time, by table-lookup selects exactly that stored limit value which corresponds to the magnetic field just measured. For the purpose of automatic limit setting, the app takes into account the distance and/or the angle from the smartphone to the device under test. The service technician will hold the smartphone in different positions each time a measurement is made. In certain situations it is of advantage if the smartphone is placed on a table or the like, close to the device under test. This avoids the error source of vibrations caused by the human hand.

The device under test may be an electronic or electromechanical device, such as a solenoid valve or the stator or rotor of an electrical motor or a linear actuator. Such devices incorporate inductive loads conducting electrical DC or AC currents.

The app according to the invention is programmed to comprise a direct or alternating current magnetic field evaluation unit. Due to the difference in dynamics of a static and an alternating magnetic field, the software application of the smartphone is divided into two units. One set of coding is used for the alternating magnetic field, another for the static field. The advantage of this is that the app can handle both alternating and direct magnetic fields. Accordingly, the app can be used for detecting DC magnetic fields as well as AC magnetic fields. The activation of the respective units is in one embodiment done automatically by the app, based on sensor measurements, hereby obtaining a seamless switching from a DC measurement to an AC measurement. This switching may be done automatically by the app without the intervention of the user. If the service technician desires to check whether the coil of a solenoid valve is intact, the smartphone with activated app can be held directly and close to the valve without any prior

knowledge of the valve being an AC or DC valve. Alternatively, in another embodiment, selection of the direct current or alternating current magnetic field evaluation unit may be done by the service technician pressing a button on the graphical user interface of the app.

Advantageously, the app may comprise a digital sample and hold circuit accessing an application programming interface (API), which in turn accesses the operating system (iOS, Android) of the smartphone and/or an electronic measurement circuitry of the sensor. The sampling rate in the digital sample and hold circuit may be kept the same in the app, irrespective of the operating system of the smartphone, either an iOS based smartphone or an Android based smartphone. The sampling rate and the holding time of the app according to the invention will preferably be identical when used in iOS and Android. This has the advantage that the magnetic field data brought into to the app from the API are normalized, i.e. always have the same format, irrespective of whether the operational system of the smartphone is iOS or Android. Thus, there is not a need for two different digital sampling systems in two different apps.

In an even further embodiment the app may be communicating wirelessly, via the smartphone, with a controller controlling the energization of the device under test. The app may transmit control signals, such as "on", "off", "current limit" or "current sweep" to the controller and simultaneously display the presence or not of a magnetic field from the device. The advantage of such a closed communication loop is that a detailed testing of the industrial device is obtained. The app may contain a pre-programmed test sequence communicated to the controller of the device, and testing the device under different load conditions, hereby establishing tables of power – magnetic strength, current – magnetic strength or voltage – magnetic strength relations. During trouble shooting, operational disruptions of the device in certain working points may be visualized by the graphic in the app when making, e.g., a current sweep. The controller is typically a programmable logic controller (PLC) or a controller built into the device under test, including wireless communication electronics.

The invention further relates to a method for calibrating a smartphone app used for testing the presence or not of a magnetic field in an industrial product incorporating an electrically energized coil. The method requires using a smartphone, a magnetic field sensor built into the smartphone and a software application (app) implemented in the smartphone, the app comprising a direct magnetic field evaluation unit and an

alternating magnetic field evaluation unit. The calibration method is characterized by the following steps:

a) placing the smartphone within a range of 0-50 cm from the industrial product,
b) starting the app, thereby activating a magnetic field measurement by the sensor,
c) activating the direct magnetic field evaluation unit or the alternating magnetic field evaluation unit,
d) during the measurement in b), adjusting, in the app, a direct current magnetic field detection limit (DC_{lim}) to a desired level, and
e) using this direct current magnetic field detection limit (DC_{lim}) as threshold for further testing the presence or not of a magnetic field in an industrial product.

With a calibration procedure as described, the magnetic stray fields in the environment are immediately eliminated, and sensor specific limitations in resolution or limitations in the (to the app programmer unknown) signal processing method of the smart phone are compensated. The calibration step can be made towards a permanent magnet with a known magnetic strength, using this as a reference, or towards a functioning and electrically energized industrial component such as a solenoid valve.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in further detail with reference to the accompanying drawings in which

Figure 1 shows a prior art application using a smartphone for detecting a magnetic field from a device under test,

Figures 2a, 2b and 2c show diagrams of magnetic field strength over time and the calibration of an app according to an embodiment of the invention, and a direct current magnetic field limit (DC_{lim}),

Figures 3, 4 and 5 show app screens according to a first embodiment of the invention displayed on a smartphone,

Figure 6 is a flow chart showing a sequence of main steps in an app according to an embodiment of the invention, and

Figure 7 shows a second embodiment of the invention including wireless communication from smartphone to a controller.

DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 shows the prior art. A magnetic field testing situation 1 comprises a handheld electronic unit, such as a smartphone 2, incorporating a magnetic field sensor 3. The smartphone 2 is brought close to a test object 4, in this example an electrical motor, and the motor is energized by alternating current. An electromagnetic field 5 will be generated by the coils in the motor and detected by the sensor 3. The magnetic signal is processed by internal circuitry (not shown) of the smartphone 2, and the processed signal 8 is outputted from the circuitry and read by an app 6, processed again and displayed as a graphic 7 on the smartphone screen 9. The arrow 8 in the figure indicates the signal coming from sensor 3.

In situations where the device under test is not an alternating current device, but a direct current device, the electromagnetic field 5 will often be weak and may disappear because the level of background magnetic radiation is bigger than the signal strength. This is relevant in industrial surroundings. This is particularly the case if the device is a low current actuator, such as a solenoid valve or a linear actuator. In solenoid valves the DC activation current is by example around 300 mA for a 24V valve. Figures 2a, 2b and 2c show measurements of direct current generated magnetic fields over time. In Figure 2a, the true DC magnetic field signal B, generated by the device under test, is below the true magnetic background level F. This true DC magnetic signal B cannot be extracted from the true magnetic background level F, unless special digital filtering processes are applied. In Figure 2b we see a situation where a signal output A from the sensor 3 is much higher than the true DC magnetic field signal B, generated by the device under test. "A" is the uncalibrated signal output from the sensor. This error is caused by the sensor 3, the circuitry and its processing software not being calibrated to the app. The amplification of signal 8 (Figure 1) is too high. According to the invention, it is now suggested to modify the uncalibrated output signal A from the sensor 3, and lowering this output signal in a direction as shown by the arrow c in Figure 2b. When inputted into the app, the output signal from sensor 3 is calibrated, and the calibrated curve shown as

curve DC_{lim} in the figure, and from this limit value, the inventive app will decide on the presence or not of a magnetic field during later measurements. Turning now to Figure 2c, correspondingly if the uncalibrated DC magnetic field signal from sensor 3 has too low an amplification, it looks like curve D close to the level of the true magnetic background level F, but far from the true DC magnetic field signal B. The detection range of the app will be very narrow and difficult for the service technician to use because the background level is so close to the uncalibrated signal. In this case, the sensitivity of the app must be increased because the signal 8 coming from sensor 3 has not been adequately amplified. In order to calibrate away this error, the uncalibrated sensor signal output D is raised in a direction shown by the arrow g. Thus, according to the invention, the calibration of the app means setting a magnetic field detection limit DC_{lim} as close to the true DC magnetic field signal B as possible, as shown in Figure 2c. Then the combination of sensor 3, processing electronics and app 6 is calibrated and ready for detecting the presence or not of a magnetic field from a device. The above text relates to DC magnetic fields, the same considerations apply for AC magnetic fields.

Figures 3, 4 and 5 show an app according to an embodiment of the invention and how the calibration is made in practice. After activating the app, the screen 10 will look like the one shown in Figure 3, and the app will be in the AC magnetic field measuring mode. At the bottom of the app, a menu with four buttons, AC, DC, Tests and About, are displayed. The buttons AC and DC reflect the two measurements modes AC and DC used to measure, respectively, alternating and non-alternating magnetic fields. Under Tests the service technician can record the measurements and attach a picture. It is furthermore possible to send the picture to an e-mail address. Above the buttons is a slider 11 with an indicator 16. The indicator 16 can be moved back and forth along the line, either by direct manipulation on the touch screen or by activating the plus or minus buttons 17. The plus and minus buttons 17, or the slide 11, correspond to moving in directions g or c in Figure 2b. Alternatively, the volume buttons at the side of the smartphone chassis can be used. The slider 11 sets a threshold, namely the magnetic field detection limit (DC_{lim}), at which an indication of the presence or not of a magnetic field is activated, in the current example 7 μT. If the signal is above the threshold DC_{lim}, it will it be considered a magnetic signal which should be handled. If it is below, it will be ignored. Above the slider 11 is a disc 12, e.g. in colors red and white. If the output from the sensor is above DC_{lim}, the disc 12 will start rotating, thus indicating a detected AC field. The direction of rotation of the disc 12 reflects the rotational direction of the magnetic field of the device to which the tool is applied.

Pressing instead the DC button, the app screen looks like Figure 4. The layout of the screen is the same as in Figure 3a, except for a gray circle 15 with a dot 14 at the center. This color code is intended for showing "no detection". The slider 11 is set for a threshold level DC_{lim} of 579 µT for the strength of the magnetic field to be detected. As the output from the sensor is only 59 µT, no detection is indicated. If the strength had been above the threshold, the screen would change to the look shown in Figure 5. The magnetic field strength in Figure 5 is reflected by a magnitude listed in the upper right corner of the screen. The size of the center dot 14' indicates the strength relative to the threshold DC_{lim}. So the bigger the dot 14, the closer to the threshold is the strength. Dot 14 has expanded into large dot 14'. In Figure 5 the direct current magnetic field detection limit DC_{lim} – the threshold – is set to 376 µT, and the measured field strength is 883 µT. As the latter is bigger than DC_{lim}, the graphic 15 changes color from grey to red, and because it is more than twice the strength the dot 14, is now filling the full circle.

Solenoid valves can be divided into AC and DC solenoid valves depending on the nature of current that is needed to activate the solenoid valves. An AC solenoid valve is driven by an alternating current, generating an alternating magnetic field in the solenoid valve. This field is detected in the AC mode. If the solenoid valve is a DC solenoid valve, the signal will have to be detected in the DC mode.

Figure 6 is a flow chart showing the steps that are performed by the inventive app and the service technician. After starting the app in step 20, the service technician will, in step 21, have to select either the DC or AC test mode. If selecting DC mode, a DC calibration 24 is performed, as described above. After finishing the calibration, DC measurements with the app are performed in step 25. The result is displayed on the screen of the phone, step 26, and in step 27 the service technician must decide if he is finished or not. If "yes", the procedure is ended in step 29. In a variant of step 21, the app automatically detects whether the signal is an alternating field or a static field.

The app according to the invention processes the (conditioned) signal incoming from sensor 3, and discards signal contributions from the magnetic field of the earth, from the smartphone doing the test, e.g. its antennas, and from any other magnetic fields characterizable as background noise. The earth's magnetic field is static compared to the device under test, and the smartphone's magnetic fields are mostly static relative to the smartphone itself. These two sources of undesired signal can be measured over time and cancelled out, using a correlation with the movement of the smartphone. These

processing steps can be done by iOS, using the correct application programming interface (API) for obtaining magnetic readings. However, the API used for reading the magnetic field does not give any information about the sample rate used by the smartphone circuitry, nor does it give an option for setting a desired sampling rate by the app through the API to the smartphone circuitry. Therefore, a digital sample-and-hold at a predetermined sample rate is used to keep further processing consistent between different measurement devices. In other words, the same sample and hold system is used in the app for iOS and Android smartphones, hereby levelling out differences in their respective sampling and processing flows. The magnetic readings supplied by the iOS are provided in three components, namely a magnetic field strength in each dimension (x,y,z) in μT. The total strength can be calculated by using the magnitudes of each of the three components and converting them into a single, scalar value in μT for the electromagnetic field.

Staying with Figure 6, a calibration is also performed in step 22 if choosing AC in step 21. After calibration, a measurement of the device under test is performed in step 23. For measuring an alternating magnetic field, the signal is, for example, held for 1 second and sampled 64 times. This allows measurements on signals having a frequency of up to 32 Hz. After the sampling, the sampled signals are processed, which involves removal of the DC component, applying a digital filter and making frequency analysis by means of a fast fourier transformation (FFT). In step 26, it is determined whether the measured magnetic field value is bigger than the set magnetic field limit value. If this is the case, a graphic, an animation, a vibration and/or a sound signal will be activated. In step 27, the service technician takes a decision whether he has finished the maintenance or troubleshooting, or whether he will continue. If not finished, he can repeat the sequence and go from step 30 to the beginning (or to steps 23 or 25), or he can choose an advanced wireless closed loop magnetic field-testing procedure in step 28 described below.

Figure 7 shows a magnetic field measurement of a solenoid valve 50, and relates to step 28 in Figure 6. The valve has an inlet 51 and an outlet 52, and a valve plunger 53 moving upwards or downwards in dependence of electrical energization of the coil 54. The crosses symbolize a coil which is energized by electrical current and generates magnetic field 55. The field 55 can be a static field or an alternating field. A controller 57, such as a PLC, is supplying current and control signals via cable 58 to the terminal box 56 of the valve. After having calibrated the app 64 of the smartphone 60 to the magnetic field sensor 61, a measurement of the magnetic field 55 is initiated. Sensor 61

is brought into the range of the magnetic field 55, and in case the measured magnetic field 55 is higher than the set magnetic field limit, a graphic indication 63 is given on the screen 62. The inventive app 64 is, in this embodiment, programmed with further functionality. It communicates, via the smartphone 60, wirelessly with controller 57, using preferably point to point Bluetooth® communication 59. The communication can be one- or bi-directional. Via this communication link, a test sequence of the valve is communicated to the PLC. The test sequence consists of a fast series of opening and closing signals and the corresponding magnetic field response 55 is logged by smartphone 60, and read out as a graphic 65 in the app 64. Other test sequences are possible. Having a closed loop testing setup as described, enables performing a health check of the valve and its coil, making a performance profile which can be stored in the app. This performance profile can later be compared to a new performance profile, and any drop in performance may lead the service technician to exchange the valve. In a variant of this setup, the controller 57 is built into the terminal box 56, i.e. the valve has its own intelligent control and communication and communicates directly with the smartphone 60.

Claims

1. An app for use in a smartphone (2,60) which comprises a magnetic field sensor (3), said app (6) displaying, on a screen (9) of the smartphone, the presence or not of a magnetic field generated by an electrical or electronic device (4,50) being measured by the magnetic field sensor, wherein a DC or AC current magnetic field detection limit (DC_{lim}, AC_{lim}) is set in a calibration step (22,24), and where the presence of a magnetic field generated by said device (4,50) is indicated on the screen (9,62) only if the measured DC or AC current magnetic field (DC_{meas}, AC_{meas}) is larger than the set magnetic field detection limit (DC_{lim}, AC_{lim}) (26), characterized in that the app comprises a direct magnetic field evaluation unit (24) and an alternating magnetic field evaluation unit (25), and in that the activation of the respective units is done automatically by the app (6,64), based on sensor measurements (21), or is done manually (21) by the user of the smartphone.

2. An app according to claim 1, wherein the magnetic field detection limit (DC_{lim}, AC_{lim}) set in the calibration step (22,24) is set by a human user of the app, said human user adjusting a sensitivity scale (11) displayed in the app (6,64) on the screen (9,62) of the smartphone.

3. An app according to claim 1, wherein the magnetic field detection limit (DC_{lim}, AC_{lim}) is set automatically in the calibration step (22,24) in the app by letting the app adjust the amplification of the sensor signal (8) fed to the app.

4. An app according to any of the preceding claims, wherein the electrical or electronic device (4,50) is an electronic or electromechanical device, such as a solenoid valve, a linear actuator or the stator or rotor of an electrical motor incorporating a coil carrying an electrical direct current.

5. An app according to any of the preceding claims, wherein a digital sample and hold circuit of the app (6,64) accesses an application programming interface (API), which in turn accesses an operating system of the smartphone and/or an electronic measurement circuitry of the sensor (3), and where a sampling rate in the digital sample and hold circuit is the same irrespective of the operating system of the smartphone.

6. An app according to any of the preceding claims, wherein the app (64) communicates wirelessly, via the smartphone, with a controller (57) which controls the energization of the device (50), wherein said app transmits control signals such as on, off, current limit or current sweep to the controller and simultaneously measures a magnetic field (55), using the sensor (61), and displays the presence or not (63,65) of a magnetic field generated by the device.

7. A method for calibrating a smartphone app used for testing the presence or not of a magnetic field in an industrial product (4,50) incorporating an electrically energized coil, the method using a smartphone (2,60), a magnetic field sensor (3) and an app (6,64) implemented in the smartphone, the app comprising a direct magnetic field evaluation unit (24) and an alternating magnetic field evaluation unit (25), the calibration method being characterized by the following steps:
   a) placing the smartphone within a range of 0-50 cm from the industrial product (4,50),
   b) starting the app (6,64), thereby activating a magnetic field measurement, using the sensor (3),
   c) activating the direct magnetic field evaluation unit (24) or the alternating magnetic field evaluation unit (25),
   d) during the measurement in b), adjusting, in the app, a direct current magnetic field detection limit (DC_{lim}) or an alternating current magnetic field limit (AC_{lim}) (11) to a desired level,
   and
   e) using either or both of these direct and alternating current magnetic field detection limits (AC_{lim}, DC_{lim}) as a threshold for determining the presence or not of an electromagnetic field emanating from the industrial product.

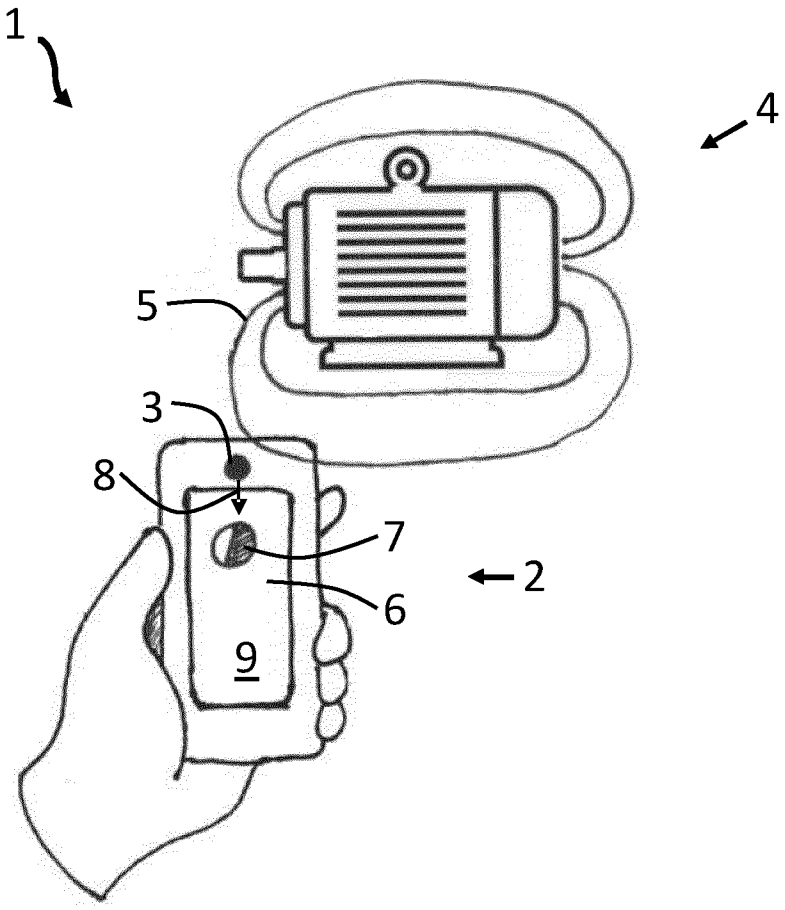


Fig. 1

Fig. 2a

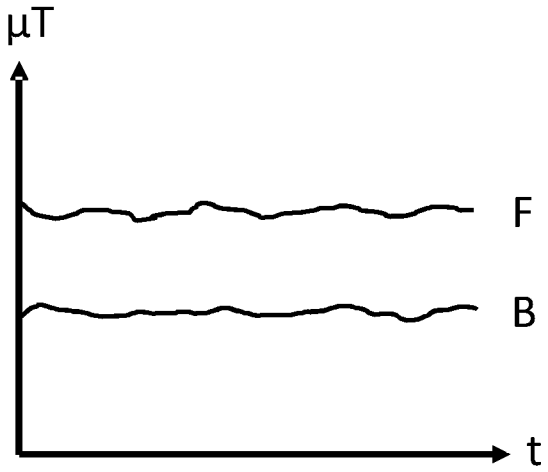


Fig. 2b

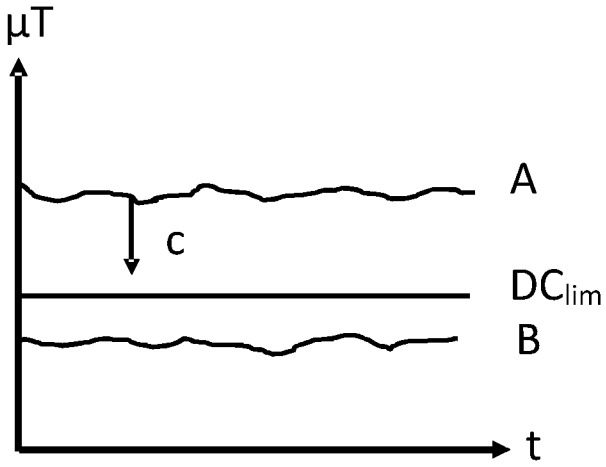
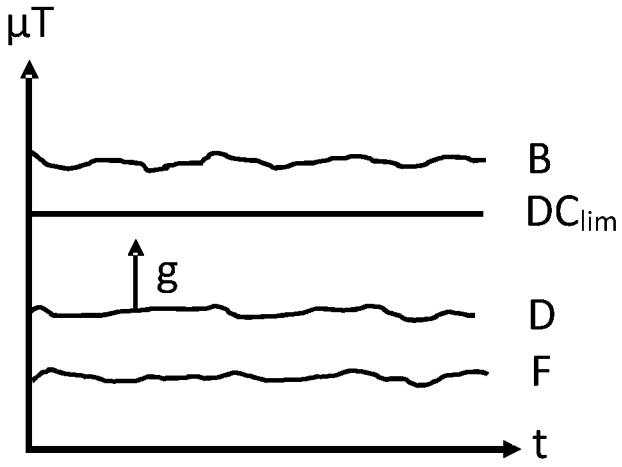


Fig. 2c



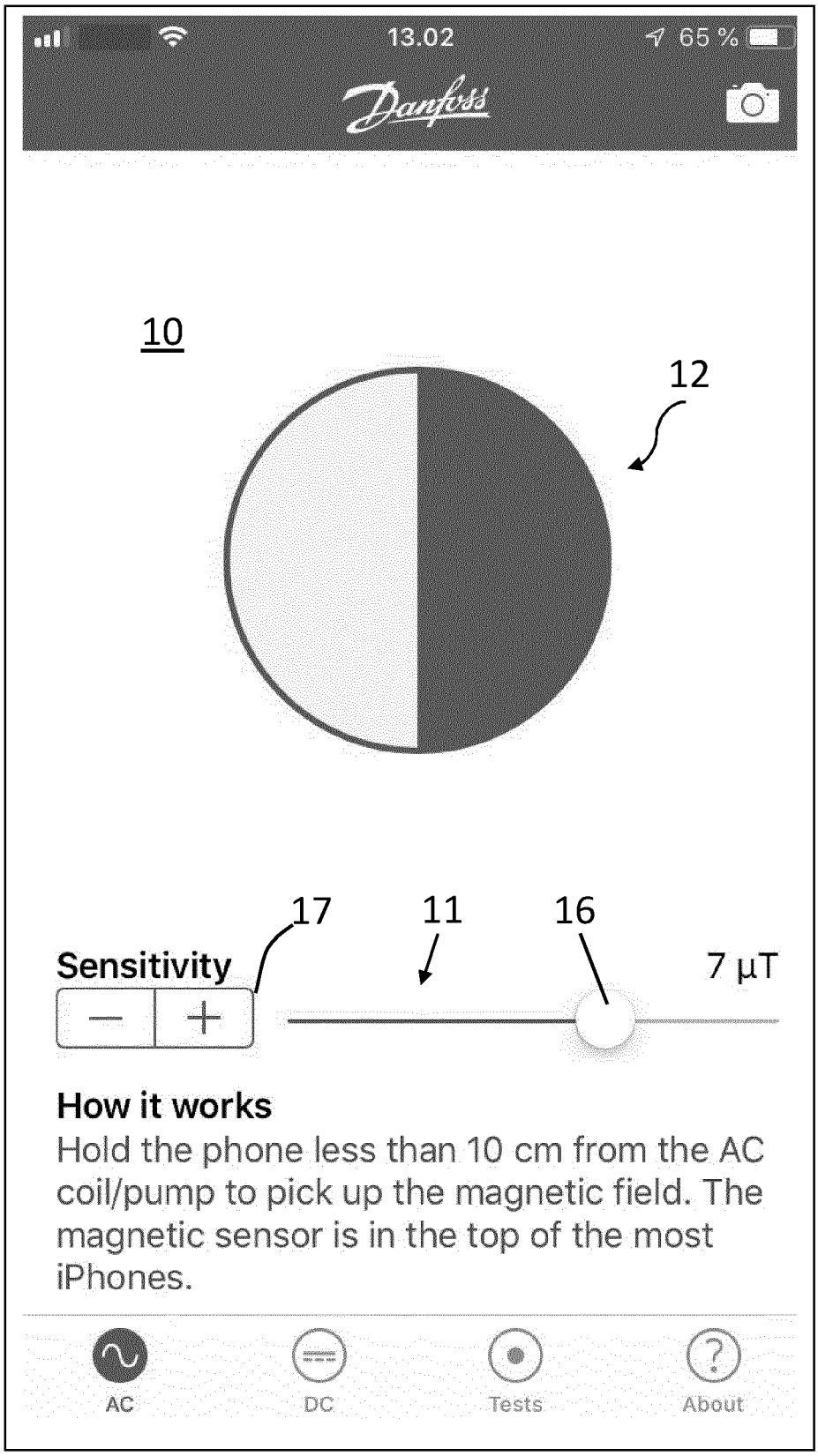

13.02
65 %
Danfoss
10
12
17
11
16
Sensitivity
7 µT
How it works
Hold the phone less than 10 cm from the AC coil/pump to pick up the magnetic field. The magnetic sensor is in the top of the most iPhones.
AC
DC
Tests
About

Fig. 3

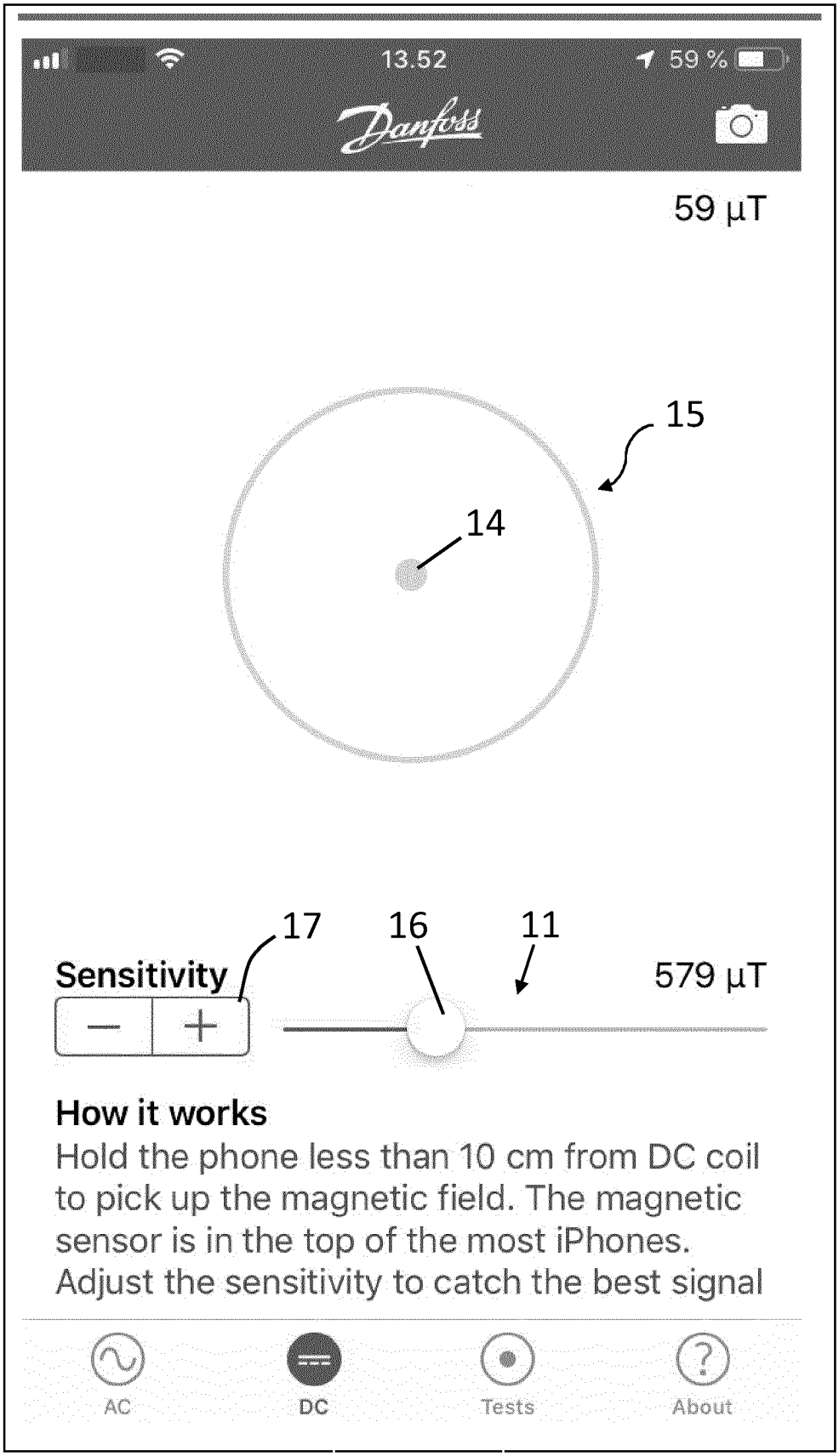

13.52
59 %
Danfoss
59 µT
15
14
17
16
11
Sensitivity
579 µT
How it works
Hold the phone less than 10 cm from DC coil to pick up the magnetic field. The magnetic sensor is in the top of the most iPhones. Adjust the sensitivity to catch the best signal
AC
DC
Tests
About

Fig. 4

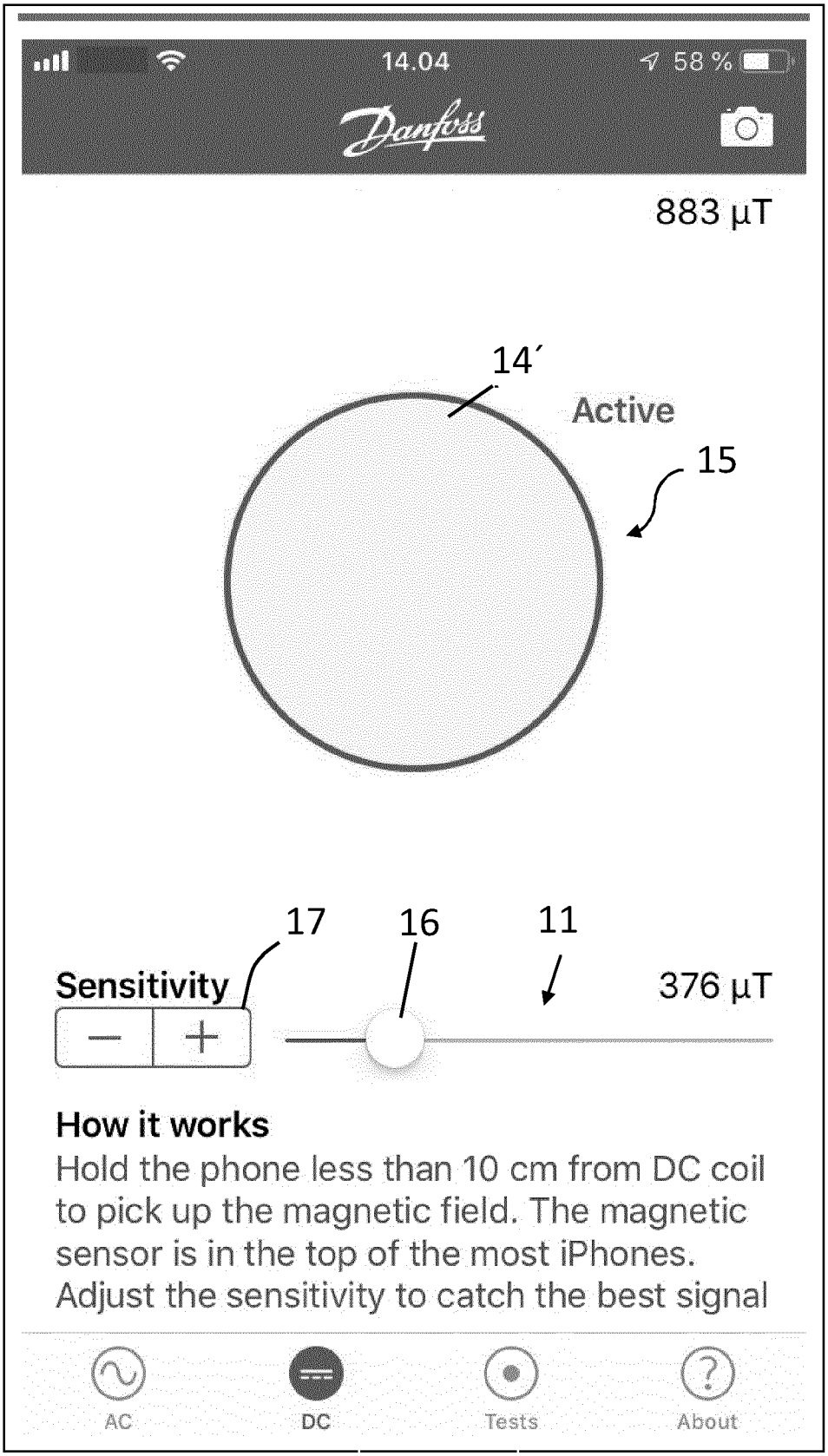

14.04
58 %
Danfoss
883 µT
14´
Active
15
17
16
11
Sensitivity
376 µT
How it works
Hold the phone less than 10 cm from DC coil to pick up the magnetic field. The magnetic sensor is in the top of the most iPhones. Adjust the sensitivity to catch the best signal
AC
DC
Tests
About

Fig. 5

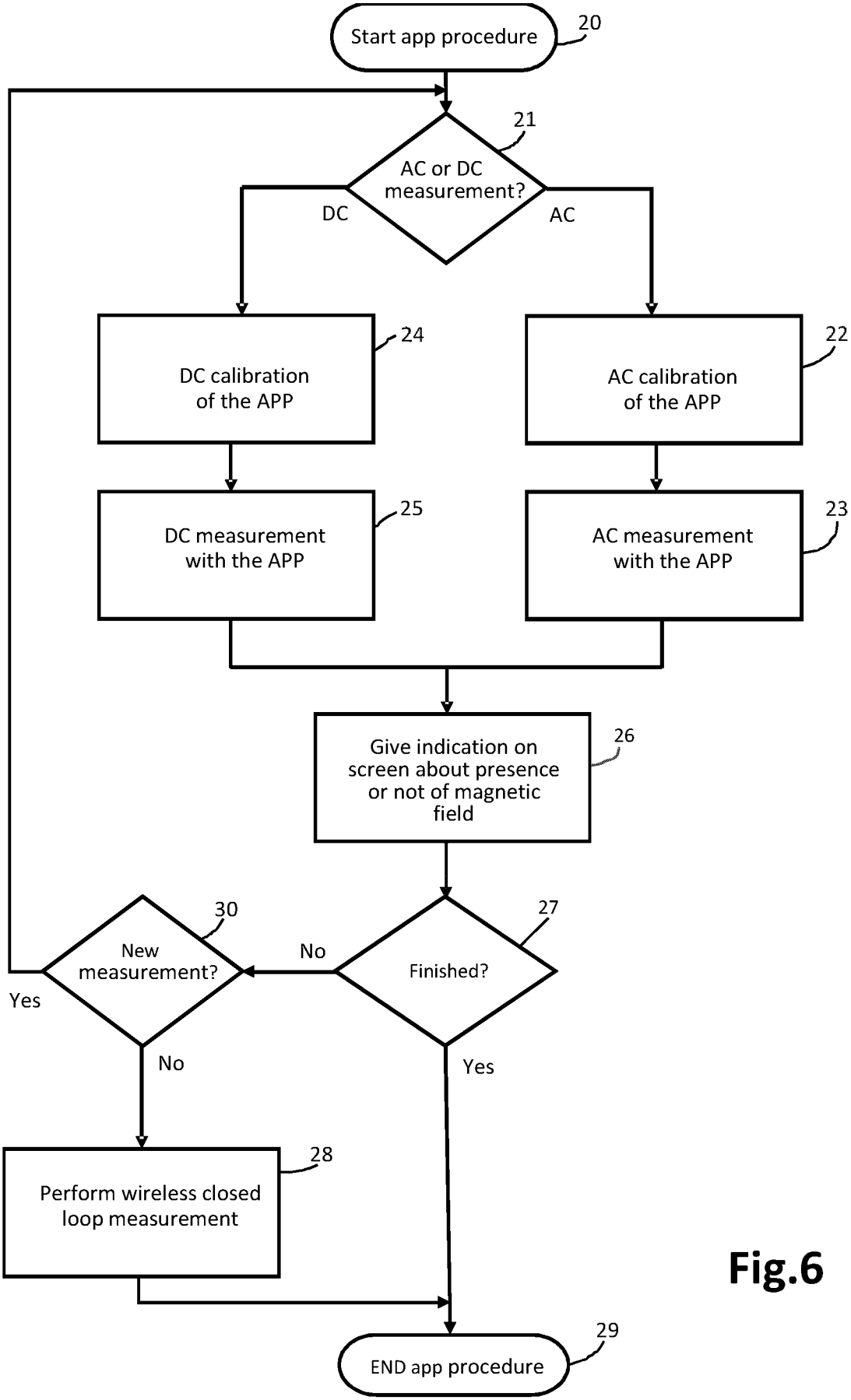

Start app procedure
20
21
AC or DC measurement?
DC
AC
24
DC calibration of the APP
22
AC calibration of the APP
25
DC measurement with the APP
23
AC measurement with the APP
26
Give indication on screen about presence or not of magnetic field
30
New measurement?
No
27
Finished?
Yes
No
Yes
28
Perform wireless closed loop measurement
29
END app procedure

Fig.6

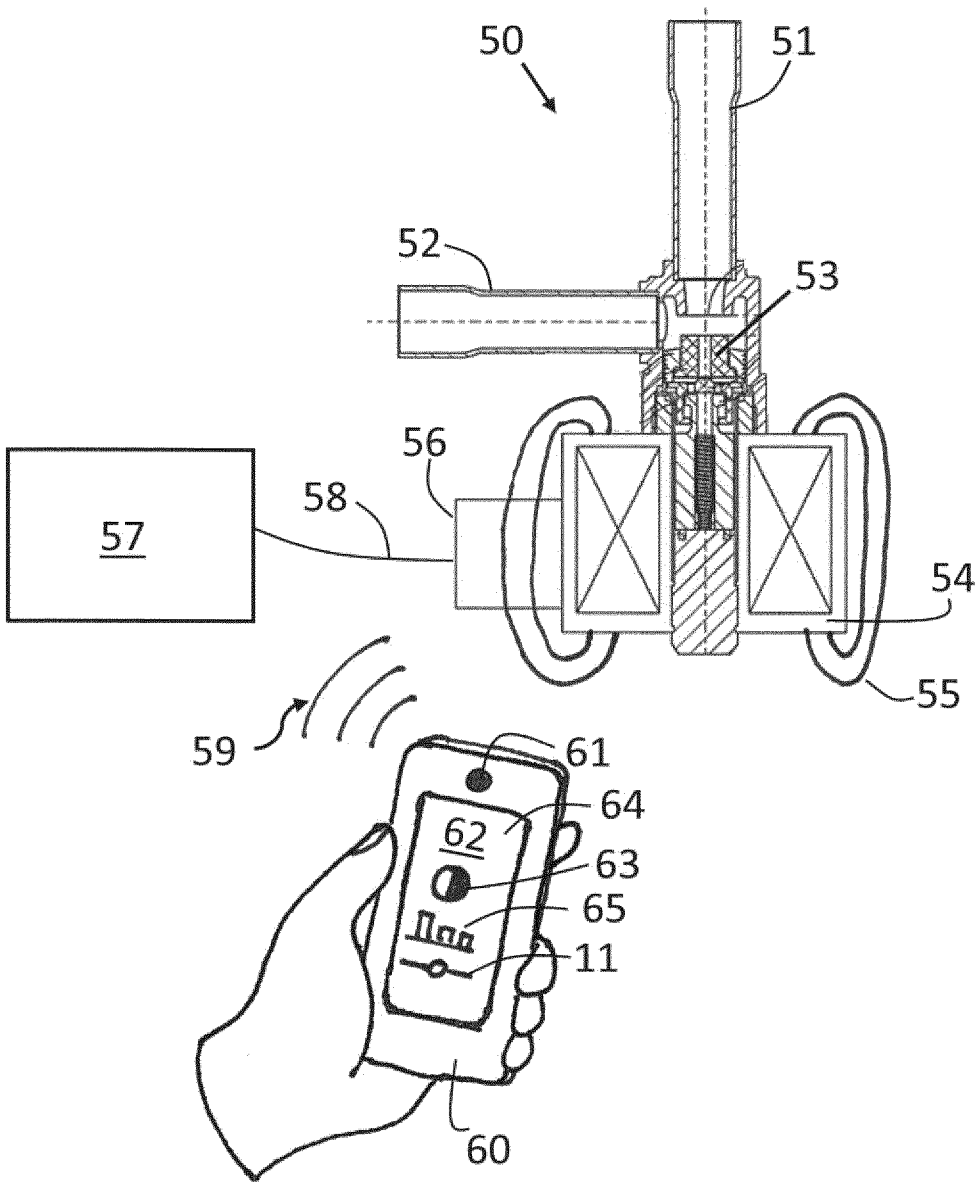


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/051294

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/00 G01R31/00
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 G06F

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	@pps Nz: "Solenoid Valve Tester - Apps on Google Play", , 6 December 2018 (2018-12-06), XP055690061, Retrieved from the Internet: URL:https://play.google.com/store/apps/details?id=com.solenoidvalvetester.android [retrieved on 2020-04-28]	1-4,6,7
Y	the whole document	3,5

-/--

[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

"E" earlier application or patent but published on or after the international filing date

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"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
29 April 2020	12/05/2020

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	Philipp, Peter

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Smf Apps Gbr: "Magnetic Field & DC Current Detector - Apps on Google Play", , 24 February 2017 (2017-02-24), XP055690079, Retrieved from the Internet: URL:https://play.google.com/store/apps/details?id=smf.detector [retrieved on 2020-04-28]	1-4,6,7
Y	the whole document	3,5
Y	Keuwlsoft: "AC Magnetic Field Meter - Apps on Google Play", , 23 October 2017 (2017-10-23), XP055690080, Retrieved from the Internet: URL:https://play.google.com/store/apps/details?id=com.keuwl.acmagneticfieldmeter [retrieved on 2020-04-28] the whole document	5
Y	WO 2018/109572 A1 (ABB SCHWEIZ AG [CH]) 21 June 2018 (2018-06-21) paragraph [0032]	3
Y	US 2010/207621 A1 (YANO SHINJI [JP]) 19 August 2010 (2010-08-19) figures 7-11	3

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2020/051294

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2018109572 A1	21-06-2018	NONE	
US 2010207621 A1	19-08-2010	CN 101806872 A	18-08-2010
		JP 5634041 B2	03-12-2014
		JP 2010217161 A	30-09-2010
		US 2010207621 A1	19-08-2010