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(71) Applicant (for all designated States except US): **BELL HELICOPTER TEXTRON INC.** [US/US]; P.O. Box 482, Fort Worth, TX 76101 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **FROMAN, Gary S.** [US/US]; 4124 Hildring Drive East, Fort Worth, TX 76109 (US).

(74) Agent: **WALTON, James E.**; Law Offices of James E. Walton, P.L.L.C., 1169 N. Burleson Blvd., Suite 107-328, Burleson, TX 76028 (US).

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(54) Title: SYSTEM AND METHOD FOR DETECTING SENSOR LEAKAGE

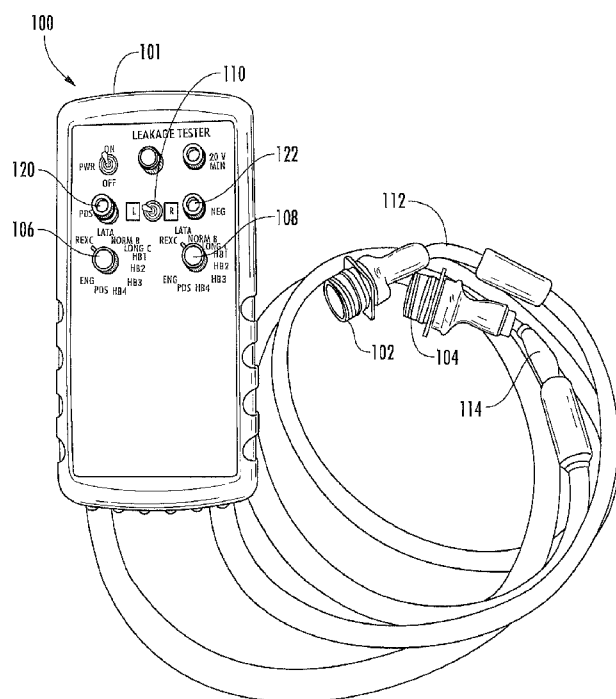


FIG. 1A

(57) Abstract: A test system for testing a sensor system includes a high-impedance resistor for forming a voltage divider with any corrosion or foreign substance that might be present between a signal conductor and a ground conductor. While a voltage is applied across the voltage divider, the voltage can be measured across the high-impedance resistor for determining whether an undesirable amount of conductance exists between the signal wire and ground. The test system also includes switching means for switching between any number of signal wires of a system undergoing testing.



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- 1 -

SYSTEM AND METHOD FOR DETECTING SENSOR LEAKAGE

Technical Field

The present application relates to systems and methods for testing sensors and systems including sensors. In particular, the present application relates to systems and methods for detecting the leakage of an electrical current in sensor systems.

5 Description of the Prior Art

Sensors such as those used on various types of vehicles are susceptible to contamination in their connectors that will degrade the sensor signal. This contamination might include such things as hydraulic fluid, gear oil, aluminum particles, and iron particles. This connector contamination is very difficult to detect and corrupts
10 the data that is supplied by the individual vibration sensors to the monitoring computer. It has also been demonstrated that some defective sensors will couple some signal wires to the sensor case. The high impedance continuity between individual pins to connector shell can affect both amplitude and phase of the sensor signal.

Typically, connectors and wiring are tested with a common multimeter that
15 measures continuity between individual sensor wires and the shell of the connector. This technique is not effective in measuring electrical continuity caused by contamination because the typical ohm meter operates at a low voltage of less than one volt. This low voltage is not sufficient to measure continuity through the contaminant. Also, checking individual wires one at a time is very time consuming, especially when
20 there may be dozens of sensors installed for vibration monitoring and multiple wires associated with each sensor.

Other high voltage testers known as hi-pot testers are also available for testing wiring and connectors, but these testers are very expensive (tens of thousands of dollars), bulky, and usually damaging to the sensitive electronics inside the sensors.

- 2 -

Hence, there is a need for an improved system and method for detecting contamination and leakage of electrical current caused by the presence of contamination.

Brief Description of the Drawings

5 The novel features believed characteristic of the system of the present application are set forth in the appended claims. However, the system itself, as well as a preferred mode of use, and further objectives and advantages thereof, will best be understood by reference to the following detailed description when read in conjunction with the accompanying drawings, in which the leftmost significant digit(s) in the
10 reference numerals denote(s) the first figure in which the respective reference numerals appear, wherein:

Figure 1A shows a plan view of a tester according to the present application;

Figure 1B shows an internal view of the tester shown in Figure 1A;

Figure 2 shows a schematic view of the tester shown in Figure 1A;

15 Figure 3 shows a simplified schematic view of the tester shown in Figures 1A, 1B, and 2;

Figure 4 shows a block diagram of a sensor system that can be tested using the tester shown in Figures 1A-3; and

20 Figure 5 shows a sensor connector that can be tested using the tester shown in Figures 1A-3.

While the system of the present application is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not

- 3 -

intended to limit the method to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the application as defined by the appended claims.

Description of the Preferred Embodiment

5 Illustrative embodiments of the method of the present application are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related
10 and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

15 In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the present application, the devices, members, apparatuses, *etc.* described herein may be positioned in any desired orientation. Thus, the use of terms such as "above," "below," "upper," "lower," or other
20 like terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the device described herein may be oriented in any desired direction.

25 Referring first to Figure 1A and 1B, disclosed herein is a sensor leakage tester 100. Tester 100 includes connectors 102 and 104 that are configured to connect to the aircraft wiring at the vibration computer disconnect. Tester 100 is a hand-held tester

- 4 -

that measures electrical leakage from sensor pins to the connector shell and cable shield. In the preferred embodiment, tester 100 does not require an external power source because it is internally battery powered, which adds to the portability of tester 100. Individual sensors are selected one at a time using the tester rotary switches 106
5 and 108 and left-right toggle switch 110, thereby enabling a plurality of sensors be tested within only a few minutes. Indications of electrical leakage for each sensor tell the maintainer that the specific sensor should be removed and cleaned, or replaced. A case 101 is configured to enclose the components of tester 100 while also providing a hand-held platform.

10 Referring also to Figure 2, a schematic view is shown of tester 100. Tester 100 includes shielded cables 112 and 114 terminating at connectors 102 and 104, respectively, for connecting the tester 100 to aircraft wiring at the vibration computer disconnect. Through these two cables 112 and 114, all aircraft vibration sensor signals are accessible. It should be appreciated that a fewer or greater number of cables may
15 be used, depending on the configuration of the vibration computer disconnect. Sensor power, signal ground, and signal wires for a given sensor are all tied together inside tester 100. By electrically connecting all of the sensor wires together for a given sensor, damage to the sensor electronics is not possible because all of the sensor wires are at the same electrical potential.

20 During operation, tester 100 applies a DC voltage (28 VDC in the illustrated embodiment, but other voltages can be used) from batteries 116 to these sensor signals through a high-impedance resistor 118, preferably in a range of 100k Ohms to 1M Ohm or more. The 28 VDC provides sufficient voltage at the contaminant to cause ionization of the contaminant, thus rendering the contaminant conductive. In the illustrated
25 embodiment, the resistor 118 is a 499k Ohm resistor. The battery power return is applied to the aircraft wiring shield (ground) through the mating connector shell. Test points 120 and 122 are provided across the resistor 118 for the operator to monitor with a voltmeter.

- 5 -

Referring now also to Figure 3, which shows a simplified schematic view of the tester 100 wherein some elements of the tester 100 are not shown in order to more clearly illustrate the operation of the tester 100. The element 124 is representative of a signal line to a sensor undergoing testing, and the element 126 is representative of
 5 signal ground line – such as a shielding, connector housing, or sensor housing – associated with the sensor undergoing testing. The resistor 128 is representative of any defect or foreign substance such as corrosion or other unwanted material that might be allowing unwanted electrical conductance between the signal line 124 and ground 126. The tester 100 is configured to detect the presence and degree of conductance
 10 provided by this unwanted material.

The resistor 118 and the resistor 128 constitute a voltage divider. Thus, the voltage across the resistor 118 can be used to determine the amount of leakage from the sensor wires 124 to the sensor case 126. The voltage V_{R1} across the resistor 118 follows the voltage divider equation as shown below in Equation (1):

$$15 \quad V_{R1} = V_{DC} \frac{R_1}{R_1 + R_2} \quad (1)$$

where V_{DC} is the input voltage from voltage source 116, R_1 is the resistance of resistor 118, and R_2 is the resistance of the leakage path resistor 128. The voltage V_{R1} is measured across test points 120 and 122, and the input voltage is known or can be measured between test point 120 and battery test point 130 shown in Figure 2. The
 20 resistance R_1 is also a known quantity. Thus, Equation (1) can be rearranged as shown below in Equation (2) and used to calculate the amount of leakage resistance R_2 , which is the inverse of the amount of conductance that may be present due to unwanted foreign substances or defects.

$$R_2 = R_1 \left(\frac{V_{DC}}{V_{R1}} - 1 \right) \quad (2)$$

- 6 -

The Equations (1) and (2) can be used to create a look-up table such as Table 1 below, which an operator or computer can use to determine whether the sensor has passed or failed the test. It should be noted that the values shown in Table 1 are merely exemplary based on the exemplary values of the present embodiment for the voltage V_{DC} and the resistor R_1 . The values in Table 1 will vary depending on the actual voltages and resistor values used in actual implementations of the tester 100.

VOLTS DC	OHMS
0.1	140 M
0.2	70 M
0.5	28 M
1.0	14 M
2.0	7 M
3.0	4 M
4.0	3 M
5.0	2.3 M
6.0	1.8 M
7.0	1.5 M
8.0	1.3 M

Table 1

Referring now also to Figure 4, which shows a block diagram of a Health and Usage Monitoring System (HUMS) 200 of an aircraft. The system 200 is shown merely in order to provide an example of a system having sensors that can be tested by

- 7 -

tester 100. Other sensor systems can also be tested by various embodiments of tester 100. The system 200 includes a central processing unit 202 in communication with left and right coprocessors 204 and 206. The system 200 also includes a plurality of sensors, generally designated as sensors 208. The rotary switches 106 and 108 in
5 concert with the toggle switch 110 allow the user to select one of the sensors 208 at a time for measurement. The L/R toggle switch 110 allows the user to select the sensors on the left side of the aircraft or select the sensors on the right side of the aircraft.

Referring now also to Figure 5, which shows an exemplary sensor connector 501. Sensor connector 501 has a plurality of sensor pins 503 and a connector shell
10 505. During testing, tester 100 ties together all the sensor pins 503 associated with a given sensor. Tester 100 uses connector shell 505 as a signal ground line.

It will be appreciated that embodiments of the tester 100 can be made completely portable, inexpensive, and battery operated. However, alternative embodiments can include further complexity. For example, alternative embodiments can include a built-in
15 functionality such as a built-in volt-meter and a processor for determining whether the sensor passes or fails based on the measured voltage across resistor 118. Such alternative embodiments can include a display, such as a pass/fail indicator, for displaying the test results.

It will also be appreciated that alternative values can be measured other than the
20 voltage across resistor 118 for determining a pass/fail condition. For example, the amount of electrical current passing through resistor 118 can instead be measured, and the pass/fail condition can be determined based on the amount of electrical current, or based on a calculated voltage, where the voltage is calculated using the known resistance of resistor 118 and the measured current according to Ohm's Law ($V=IR$).

25 The tester 100 can test for electrical current leakage from a signal line to shield or other ground in a convenient effective way without risking damage to the sensors. Testing all of a plurality of an aircraft's (or other vehicle's) sensors' wiring can be

- 8 -

achieved in only a few minutes using the rotary switches 106 and 108 instead of hours or days compared to conventional ohmmeter or hi-pot testers. The tester 100 provides enough voltage to sense the leakage current without risk of damage to the sensors or the sensor wiring. Damage to sensors is not possible because all of the sensor wires
5 are electrically connected to the same potential.

Thus, disclosed herein is a test system for testing a sensor system, where the test system comprises a test-system connector, a high-impedance resistor, a selector switch, a voltage source, and first and second test points. The test-system connector is configured for mating with a sensor-system connector. The test-system connector
10 comprises a conductive housing, first and second conductive signal leads, and insulating material. The insulating material is disposed between the first and second signal leads, and the insulating material is also disposed between the housing and each of the first and second signal leads. The high-impedance resistor is connected between the housing and the signal leads. The selector switch includes first and second
15 selector-switch positions, where the high-impedance resistor is electrically connected to the first conductive signal lead when the selector switch is in the first selector-switch position, and where the high-impedance resistor is electrically connected to the second conductive signal lead when the selector switch is in the second selector-switch position. The voltage source is configured for applying a voltage between the high-
20 impedance resistor and the conductive housing of the test-system connector. The first and second test points allow for measuring the voltage across the high-impedance resistor while the voltage is being applied. The measured voltage across the high-impedance resistor can then be used to determine whether there is any leakage current in the sensor system.

25 The particular embodiments disclosed above are illustrative only, as the application may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than

- 9 -

as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the application. Accordingly, the protection sought herein is as set forth in the claims below. It is apparent that an application with significant
5 advantages has been described and illustrated. Although the present application is shown in a limited number of forms, it is not limited to just these forms, but is amenable to various changes and modifications without departing from the spirit thereof.

- 10 -

Claims

1. A sensor test system, comprising:
 - a case configured to house a circuit;
 - a power source for producing a voltage;
 - 5 a cable electrically connecting a first sensor to the circuit; the first sensor comprising a first pin, a second pin, and a grounded connector shell; wherein the circuit comprises:
 - an electrical conduit between the first pin, the second pin, and the grounded connector shell;
 - 10 a high-impedance resistor connected between the power source and the first sensor;
 - a first voltage test point and a second voltage test point across the high-impedance resistor;
 - wherein interpretation of a measured voltage across the first voltage test point
 - 15 and the second voltage test point indicates detection of a foreign substance causing unwanted electrical conductance between the grounded connector shell and at least one of the first pin and the second pin.
2. The sensor test system of claim 1, wherein the voltage is approximately 28 volts.
- 20 3. The sensor test system of claim 1, wherein the voltage causes the foreign substance to ionize so as to produce a resistance between the grounded connector shell and at least one of the first pin and the second pin.
- 25 4. The sensor test system of claim 1, wherein the first pin, the second pin, and the grounded connector shell are electrically tied together within the circuit so as to prevent damage to the first sensor during a test procedure.

- 11 -

5. The sensor test system of claim 1, further comprising:
a voltmeter for measuring the voltage across the first voltage test point and the second voltage test point.
- 5 6. The sensor test system of claim 5, wherein the voltmeter is external to the case.
7. The sensor test system of claim 1, further comprising:
a second sensor connected to the circuit with the cable;
a switch for selectively changing electrical connectivity of the circuit between the
10 first sensor and the second sensor.
8. The sensor test system of claim 1, wherein the high-impedance resistor is between 100k Ohms and 1M Ohms.
- 15 9. The sensor test system of claim 1, wherein a leakage amount of the foreign substance is realized by a resistance the foreign substance creates when subjected to the voltage from the power source.
10. The sensor test system of claim 1, wherein a leakage amount of the foreign
20 substance is calculated by the measured voltage across the first voltage test point and the second voltage test point when subjected to the voltage from the power source.
11. The sensor test system of claim 1, further comprising:
a built-in processor for determining whether the foreign substance causes an
25 unacceptable amount of leakage.
12. A tester for detecting leakage in a sensor, the tester comprising:
a case for housing a circuitry;
a cable for connecting a plurality of sensor lines from the sensor to the circuitry,
30 the circuitry comprising:

- 12 -

a voltage divider configuration such that a measured voltage across a high-impedance resistor corresponds with a leakage resistance.

13. The tester according to claim 12, wherein the leakage resistance is a result of a contamination such that the contamination causes the leakage resistance between the plurality of sensor lines and a ground.

14. The tester according to claim 12, wherein the ground is a connector housing for the plurality of sensor lines.

10

15. A method for detecting a leakage in a sensor with a tester, comprising:
using a circuitry in the tester to electrically couple a plurality of sensor wires and a sensor ground;

15
15 resistor;

taking a voltage reading across the high-impedance resistor; and
interpreting the voltage reading so as to detect the leakage.

16. The method according to claim 15, wherein the interpreting the voltage reading includes using a look-up table, the look-up table having predetermined relationships between the voltage readings and a resistance, the resistance being an indication of an extent of the leakage.

17. The method according to claim 15, wherein the interpreting the voltage reading includes using a processor in the tester, the processor being configured to use an internal look-up table for calculating an extent of the leakage.

18. The method according to claim 17, wherein the processor is configured to output a pass/fail reading on a display of the tester.

30

- 13 -

19. The method according to claim 15, wherein the taking a voltage reading includes using an external volt-meter to take the voltage reading across the high-impedance resistor.
- 5 20. The method according to claim 15, wherein the applying a source voltage to the circuitry includes switching on a power switch which applies the source voltage from at least one battery in the tester.

1/6

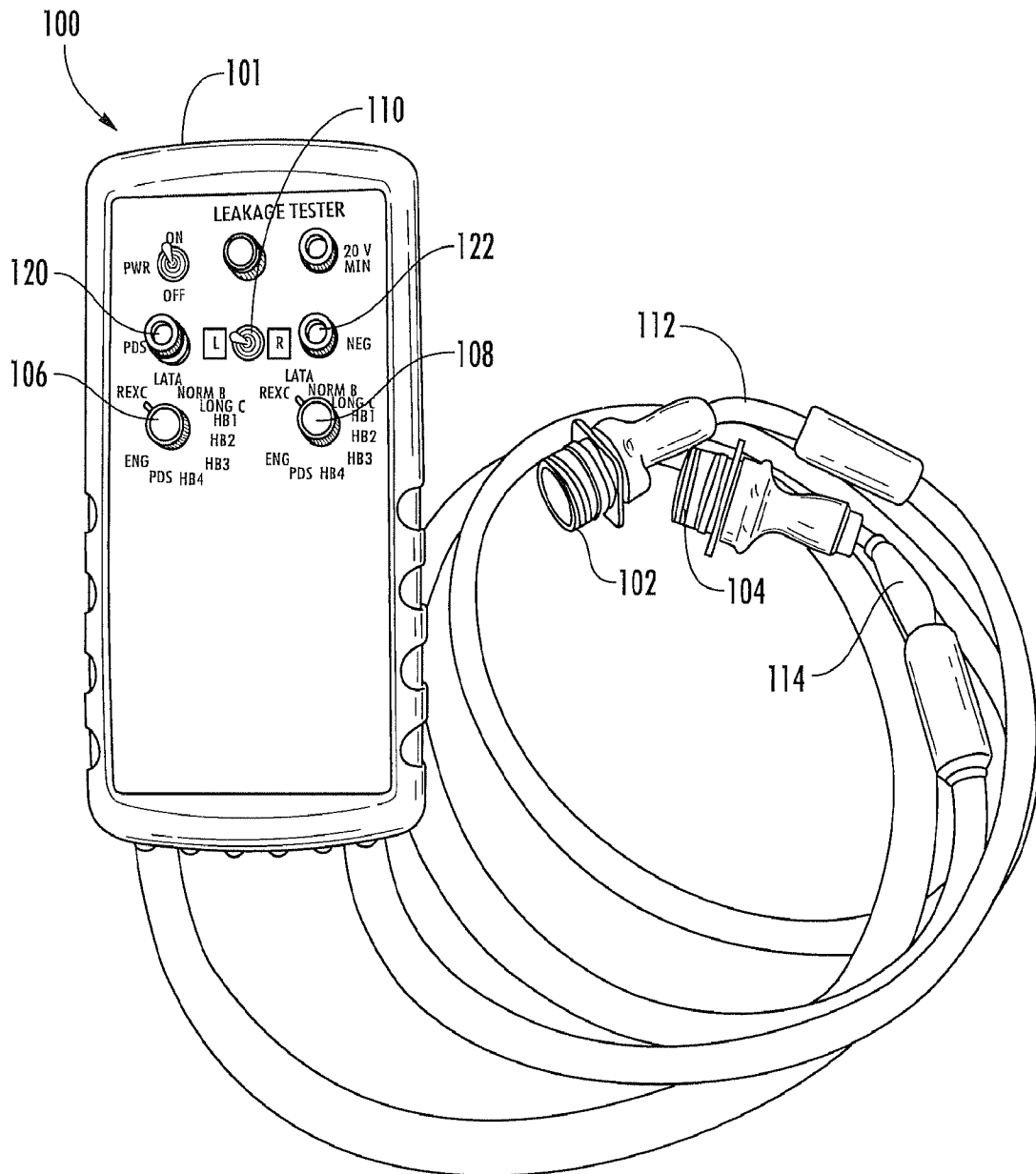


FIG. 1A

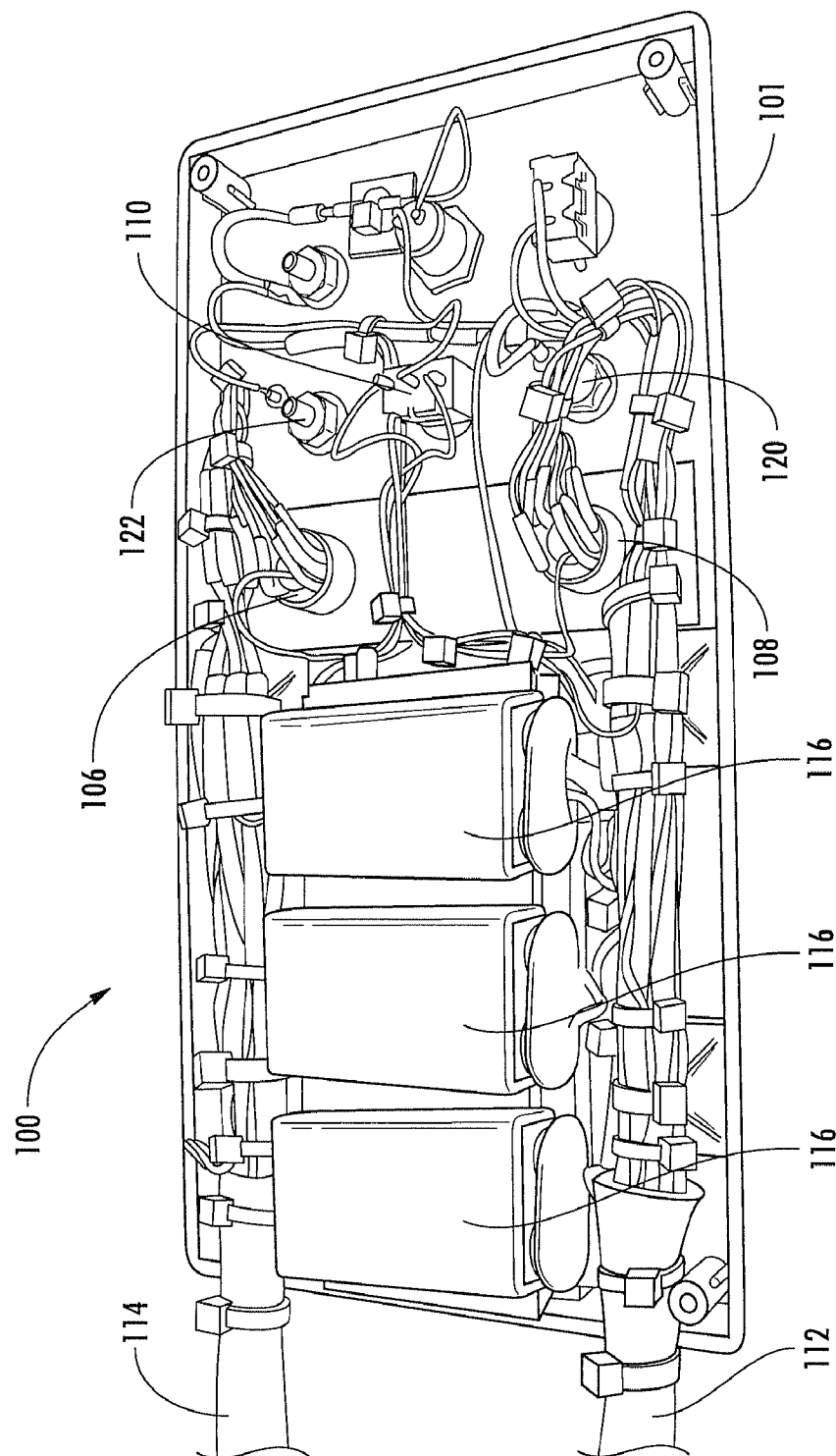


FIG. 1B

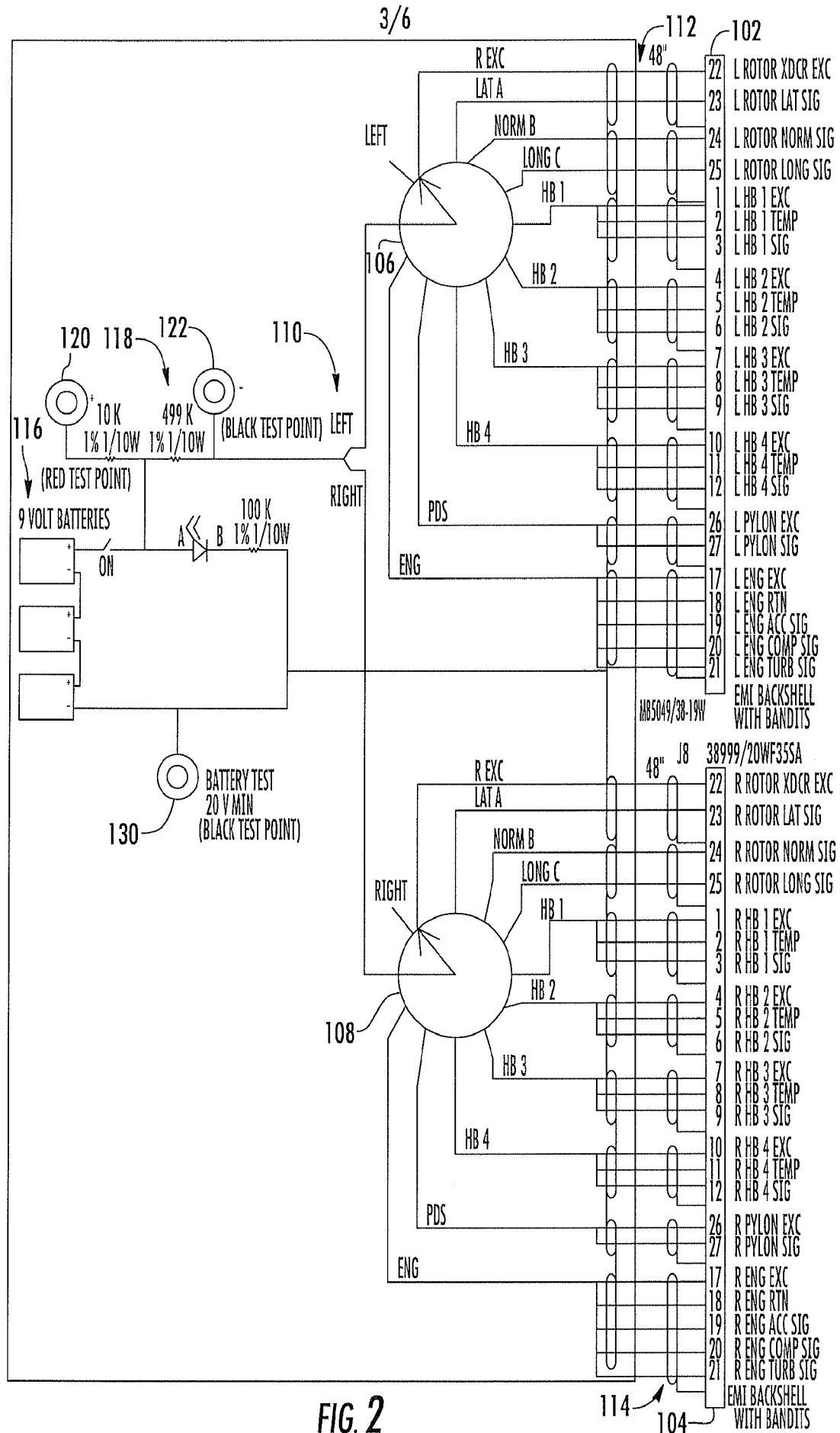
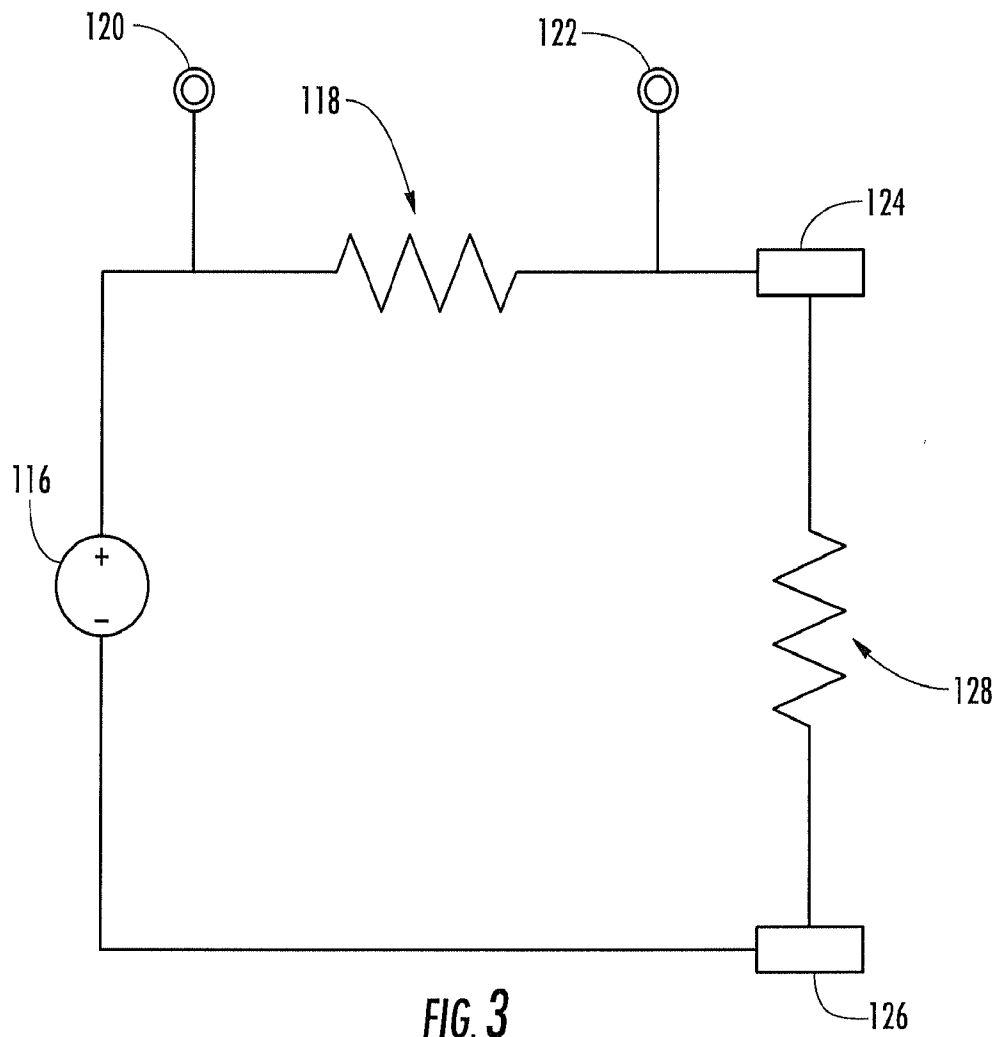


FIG. 2

4/6



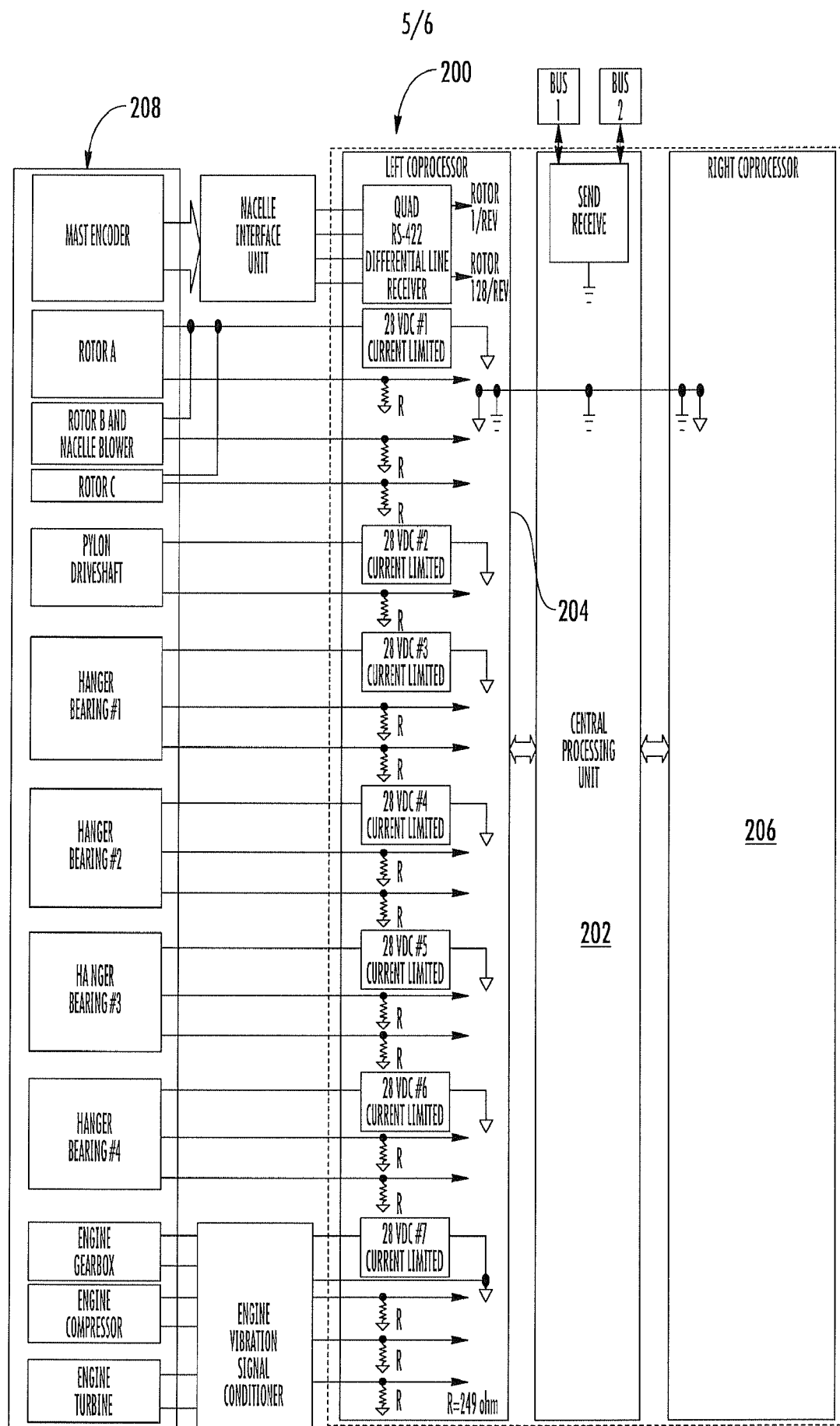


FIG. 4

6/6

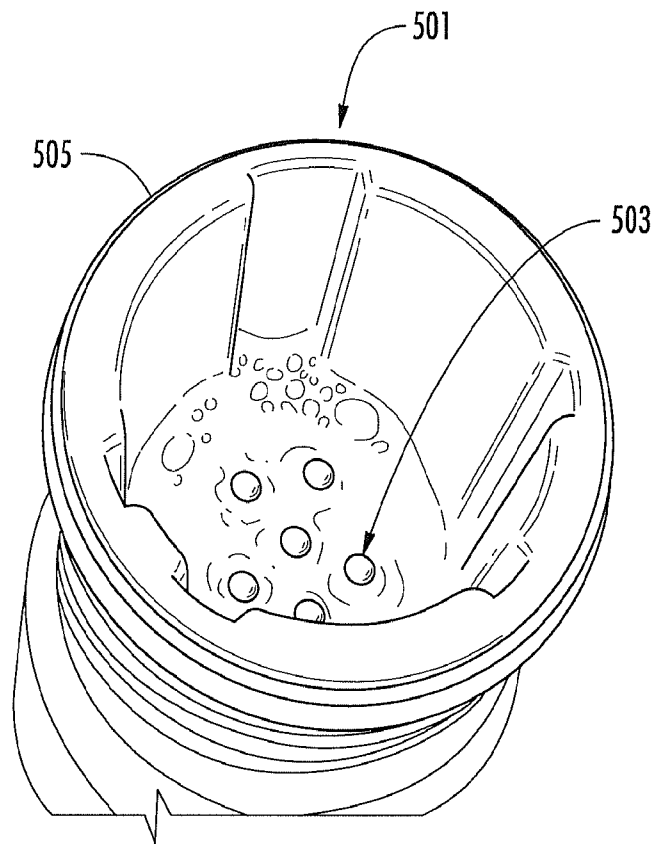


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/032657

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - G01R 31/08 (2010.01) USPC - 324/522 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) IPC(8) - G01R 31/08 (2010.01) USPC - 324/522-23, 525, 527, 691, 696, 700, 761, 763; 702/57-59 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) MicroPatent, Google Patents		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,114,856 A (BITTS) 05 September 2000 (05.09.2000) see document	1-20
Y	US 6,987,396 B2 (YANG et al) 17 January 2006 (17.01.2006) see document	1-20
Y	US 5,606,264 A (LICARI et al) 25 February 1997 (25.02.1997) see document	3, 9 and 13
Y	US 3,037,161 A (R. B. CUMMINGS) 29 May 1962 (29.05.1962) see document	2
Y	US 7,512,503 B2 (BECHHOEFER et al) 31 March 2009 (31.03.2009) see document	16-18
A	US 2008/0255781 A1 (BEARD et al) 16 October 2008 (16.10.2008) see document	1-20
A	US 5,481,194 A (SCHANTZ et al) 02 January 1996 (02.01.1996) see document	1-20
A	US 5,875,413 A (VINCI) 23 February 1999 (23.02.1999) see document	1-20
A	US 4,147,596 A (BABOIAN et al) 03 April 1979 (03.04.1979) see document	1-20
A	US 5,124,661 A (ZELIN et al) 23 June 1992 (23.06.1992) see document	1-20
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