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(54) Title: RED PALM WEEVIL LARVA DETECTION

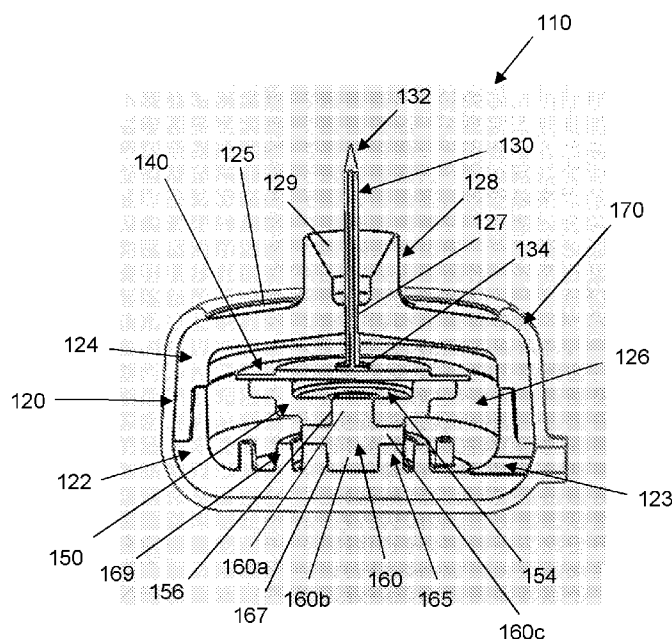


Fig. 9

(57) Abstract: A wood boring insect detector (110) comprises a housing (120) defining a hollow interior chamber (126) and including an opening (127) connecting the interior chamber to the exterior; a spacer member (128) surrounding the opening and defining an internal cavity (129); and an acoustic sensor (140) mounted within the interior chamber (126). A probe (130) projects through the opening and the internal cavity of the spacer. An exposed tip portion (132) of the probe is for insertion into a specimen (100). A base portion (134) of the probe is connected to the acoustic sensor (140). The spacer member defines a separation between the housing (120) and the specimen (100) and a depth of insertion of the probe tip (132) into the specimen. When the tip portion (132) is inserted into a specimen, wood boring insect activity within the specimen is transmitted as vibrations along the probe (130) to the acoustic sensor (140), which converts those vibrations to an output signal of a characteristic acoustic frequency indicative of the presence of wood



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boring insect activity within the specimen (100). The detector can include specially configured internal cavities/chambers (126, 129, 154), a mount (150) and a resilient pad (160), and a resilient outer sheath (170), which are physical elements that filter out much of the background noise for particularly good acoustic properties.

Red Palm Weevil Larva Detection

[0001] This invention relates to a wood boring insect detector, in particular but not exclusively a red palm weevil larva detector and an associated method of detection.

5 BACKGROUND

[0002] Red palm weevil (RPW), *Rynchophorus ferrugineus* causes fatal damage to young coconut and oil palms accounting to about 10% of the loss of crop in the World. The weevil's larvae develop within the tree stem and crown, damaging the vascular system and eventually cause the death of the tree. The top ten countries that grow coconuts are
10 Indonesia (21 million metric tons (mMT)), Philippines (15 mMT), India (10 mMT), Sri Lanka (2 mMT), Brazil (1.9 mMT), Thailand (1.3 mMT), Vietnam (1.12 mMT), Mexico (1 mMT), Papua New Guinea (0.93 mMT), and United Republic of Tanzania (0.6 mMT). If Sri Lanka is taken as an example, the coconut industry accounts for 1.5% of the GDP (around £700 million). It has been estimated that 10% of young coconut palms in Sri Lanka are lost
15 annually due to RPW attack. Accordingly, during the period of 2000–2005, nearly 200,000 young palms have been killed by RPW resulting in a financial loss of about US \$ 1,800,000. The larvae feed on the soft tissues on the stem and bud region destroying internal tissues. Early detection of infested palms at the early stage by external symptoms is difficult because the RPW larvae develop internally within the tree, hidden from sight.

20 [0003] RPW larvae produce a characteristic crunching sound as they feed on the palm fibres because, due to their morphology, they chew rhythmically at a specific frequency. It is therefore known to detect the presence of RPW larvae in palms using detectors with audio sensors; in particular, piezoelectric sensors attached to a probe inserted into a specimen tree, whereby the larvae's distinct sounds propagate through the fibrous palm
25 tissue to the probe to be transmitted to the attached sensor. However, it has proven to be difficult to discriminate the sounds characteristic of the RPW larvae from other sounds picked up by the audio sensors. For example, honey bees, water being pumped naturally internally within the tree, and the tree bending and twisting in the wind all produce sounds within the tree that are similar to those characteristic of the RPW larvae. Further difficulties
30 arise from unwanted background environmental noise external to the tree also, such as wind and vehicle noises. Attempts to mitigate these difficulties have included applying signal processing techniques to the signals output from the audio sensors to attempt to isolate the sounds of those of the RPW larvae from the unwanted sounds also picked up by the sensors, and to analyse the captured sound in real-time, supplying an audible tone
35 or visible signal when the analysis detects a sound indicative of the presence of RPW larvae. One known signal processing technique is to apply an active band pass filter in the

800–2,500 Hz frequency band, which has been identified as the effective frequency range of the RPW's acoustic emissions. A trained operator determines whether the palm tree is infested, based on the number and frequency of the positive tones or visible signals. To date, this has required a physical signal processing unit to be supplied with the detector,
5 which has meant relatively high cost units that are not well afforded by the typically rural farming communities for whom they would be of most benefit.

[0004] Recommended management methods, such as applying toxic chemical treatments (insecticides) are often not adequately practiced by the farmers due to shortage of labour and high cost of operations, as well as difficulties in obtaining the necessary
10 treatments.

[0005] Hence a reliable, inexpensive and convenient early detection method is necessary to save the infested palms.

BRIEF SUMMARY OF THE DISCLOSURE

[0006] In accordance with a first aspect of the present invention, there is provided a
15 wood boring insect detector comprising: a housing defining a hollow interior chamber and including an opening connecting the interior chamber to the exterior; a spacer member surrounding the opening and defining an internal cavity; an acoustic sensor mounted within the interior chamber; and a probe projecting through the opening and the internal cavity of the spacer and having an exposed tip portion for insertion into a specimen and a base
20 portion connected to the acoustic sensor. The spacer member defines a separation between the housing and the specimen and a depth of insertion of the probe tip into the specimen. When the tip portion is inserted into a specimen, wood boring insect activity within the specimen is transmitted as vibrations along the probe to the acoustic sensor, which converts those vibrations to an output signal of a characteristic acoustic frequency
25 indicative of the presence of wood boring insect activity within the specimen.

[0007] The configuration of the housing and the spacer member, which may be integrally formed with the housing or may be a separate component connected thereto, provides for particularly good acoustic properties; eliminating much background noise so that substantially only noises emanating from within the specimen (i.e. the characteristic
30 crunching sound produced by the insects chewing on fibres in the specimen) are picked up by the acoustic sensor and therefore, output to be heard by a user of the detector. The spacer member further helps to ensure that the tip of the probe is consistently inserted to a correct depth in the specimen so that multiple readings can be compared uniformly.

[0008] The detector may further comprise a sensor mount within the interior chamber, a
35 sub-chamber being defined between the mount and the sensor. The sub-chamber may

- taper from the sensor to the mount, and that taper may be inward or outward. The sub-chamber, and particularly the tapering volume defined by it has been found to improve the acoustic properties. The detector may further comprise a resilient pad between the sensor mount and the housing. The resilient pad is typically made with 50 shore hardness
- 5 silicone rubber. The resilient pad helps to isolate the sensor from background vibrations transmitted to the housing, such as mechanical vibrations induced from touching and scratching of the exterior of the detector and, where the specimen is a live tree, from vibrations induced through bending and twisting of the trunk and movement of the leaves, thereby further filtering out unwanted background noise from the output signal. In other
- 10 words, the resilient pad acts as a signal filter by restricting the vibrations of the acoustic sensor to substantially just those transmitted via the probe; the placement of the resilient pad between the sensor mount and the housing filters the signal coming through the probe to isolate the crunching sound of wood boring insects (e.g. RPW larvae) from other sounds.
- 15 **[0009]** The internal cavity of the spacer may be horn-shaped, tapering outwardly from a relatively narrow channel at the opening to a relatively wide mouth towards the tip portion of the probe. This horn-shaped cavity acts like the cochlear and thus further helps to filter out unwanted background noise, due to the physical shape.
- [0010]** The sensor may be a piezoelectric sensor.
- 20 **[0011]** The detector may further comprise a resistor connected in parallel with the sensor, wherein the resistor has a resistance in the range: $1\text{k}\Omega$ to $60\text{k}\Omega$; preferably $45\text{k}\Omega$ to $60\text{k}\Omega$; more preferably $56\text{k}\Omega$.
- [0012]** The probe is typically metal; preferably steel and more preferably stainless steel.
- [0013]** The housing may be cylindrical. This is a convenient shape to manufacture and is
- 25 best suited for housing a typically substantially circular acoustic sensor.
- [0014]** The detector may further comprise a resilient sheath covering at least a majority of the housing surface. The resilient sheath, typically formed of silicone, further helps to isolate the housing and more particularly the acoustic sensor within from external background noise.
- 30 **[0015]** The detector may further comprise an electrical output connector to form an electrical connection with a mating electrical input connection (port) of a portable computing device for the transmittal of the output signal to the portable computing device. The portable computing device is typically a mobile phone or the like, and typically operates under the Android™ operating system. Other operating systems are of course
- 35 available. The optional presence of the resistor connected in the sensor circuit modifies

the output signal to be suitable for certain connected devices, such as those operated under the Android™ operating system, for which the 56kΩ resistor provides the optimum value for the sensor. The electrical output connector may comprise an audio jack, such as a 3.5mm audio jack. This is one convenient and common form of electrical connector for connecting the device to the associated portable computing device (e.g. mobile phone), e.g. via the device's audio jack socket. It will be understood that other forms of connection can be made instead, such as a Lightning connector to connect to Apple™ devices.

[0016] The detector may be for use in detecting red palm weevil larvae, and the specimen may comprise a palm tree. This is a typical application for the detector, and has evident economic benefits as set out above. Alternative applications of the technology are also envisaged however, as would be understood by the skilled reader. By way of example, the specimen could be a different type of palm plant, such as a date or Canary palm. Moreover, the specimen need not be living – for example it could be wood in the form of a piece of construction timber or furniture or a ship. The insect to be detected may be different from the red palm weevil larva also.

[0017] In accordance with a second aspect of the invention, there is provided a wood boring insect detection kit comprising: a detector according to the first aspect of the invention; and a portable computing device configured to receive the output signal from the acoustic sensor in the detector and to output an audio signal for listening by an operator. The portable computing device (typically a mobile phone) may be configured to process the received output signal from the acoustic sensor and to output a modified audio signal for listening by an operator, for example through headphones connected to the portable computing device. Mobile phone ownership is typically high, so this can be exploited to advantage by carrying out the signal processing task associated with converting the acoustic sensor's output signals to a useable audible signal for listening by the operator within the phone rather than in a separate microprocessor-based signal processing unit. This therefore eliminates the need for such a separate microprocessor-based signal processing unit and the device can therefore be kept simple and inexpensive. Appropriate signal-processing software (e.g. a smartphone app) may be provided with the device (e.g. in the form of a download link).

[0018] In accordance with a second aspect of the invention, there is provided a method of detecting wood boring insects, comprising: using a detector according to the first aspect of the invention, inserting the probe into a specimen bringing the spacer into contact with the specimen to ensure the probe is inserted to the correct depth; forming a communication connection between the detector and a portable computing device, whereby the portable computing device receives the output signal from the audio sensor;

processing the output signal in the portable computing device and outputting an audio signal for listening by an operator; and the operator listening to the audio signal and deciding whether that signal includes a characteristic frequency indicative of the presence of wood boring insect activity within the specimen.

- 5 **[0019]** The processing in the portable computing device may comprise at least one of amplifying and filtering the received output signal to produce the audio signal.

- 10 **[0020]** The method may further comprise: within 5 minutes prior to the operator listening to the audio signal, first listening to a recorded audio signal known to have been recorded in the presence of wood boring insect activity. It has been recognised that the human auditory cortex has a working memory of approximately 5 minutes during which time recently heard sounds are retained. Thus, by providing for the operator to listen to an effective control signal containing a characteristic sound (e.g. of fibres being crunched at the characteristic frequency for a particular larva) within that time frame, it is easier for the operator to recognise that characteristic sound within the subsequently heard audio signal, thereby increasing the chances of correctly identifying the presence (or absence) of an insect within the specimen.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Embodiments of the invention are further described hereinafter with reference to the accompanying drawings, in which:

- 20 Figure 1 is a perspective view of a detector device according to one embodiment;
- Figure 2 is a cross-sectional side view through the detector of Figure 1;
- Figure 3 is a cross-sectional perspective view of a housing of the detector of Figure 1;
- Figure 4 is an exploded view of component parts of a detector according to one embodiment;
- 25 Figure 5 is a plan view of a sensor mount of the detector of Figure 1;
- Figure 6 is a plan view of a resilient pad of the detector of Figure 1;
- Figure 7 is a cross-sectional perspective view of the detector of Figure 1, taken orthogonally to the view of Figure 3 and additionally showing electrical connections between the sensor and an audio jack;
- 30 Figure 8 is a schematic view of a detector positioned on a specimen and electrically connected to a portable computing device and, in turn, to headphones;

Figure 9 is a cross-sectional perspective view of a detector device according to another embodiment;

Figure 10 is a photograph of a detector according to another embodiment; and

Figures 11A and 11B are photographs of the detector of Figure 10 in a
5 disassembled condition, with Figure 11B showing both upper and lower views of some of the components.

DETAILED DESCRIPTION

[0022] One embodiment of a wood boring insect detector 10 is described with reference to the accompanying drawings Figures 1 to 8. The detector 10 comprises a substantially
10 cylindrical housing 20 formed in two parts: a lower portion 22; and an upper portion 24, which fit together to define a hollow interior chamber 26. The hollow interior chamber 26 comprises two interconnected portions: an upper portion 26a and a lower portion 26b having a smaller diameter than the upper portion 26a. The housing 20 includes a central opening 27 connecting the (upper portion 26a of the) interior chamber 26 axially to the
15 exterior through an upper surface 25 of the housing. A channel 23, formed partially in the lower portion 22 and partially in the upper portion 24, connects the (lower portion 26b of the) interior chamber 26 laterally to the exterior. A spacer member 28 projects from the upper surface 25 and surrounds the opening 27. The spacer member 28 has a substantially cylindrical outer surface and an inner surface that defines, in the illustrated
20 embodiment, a horn-shaped internal cavity 29. The horn-shaped cavity 29 comprises a cylindrical channel 29a in connection with the opening 27 leading to an outwardly tapering mouth 29b. The spacer member 28 may be integrally formed with the housing 20, as shown, or may be a separate component connected thereto.

[0023] In one embodiment, the housing 20 is manufactured from a plastic material,
25 typically ABS, and is typically moulded, although it will be appreciated that other materials and other manufacturing techniques may be used instead. In one example, the housing 20 has a wall thickness of 3-5 mm, a diameter of 28-32 mm and an interior chamber length (i.e. height of the interior chamber 26 between the top side of the base portion 22 and the underside of the upper portion 24) of 8-15 mm.

[0024] An acoustic sensor in the form of a substantially circular piezoelectric sensor 40 is
30 mounted within the interior chamber 26. An electrical cable comprising a pair of electrical leads 42a, 42b extends from the sensor 40 through the channel 23 to an electrical connector in the form of a 3.5 mm audio jack 44. A resistor 46 is connected in parallel between the leads 42a, 42b. For illustrative purposes, this is shown schematically in the
35 portion of the leads external of the housing 20, but it will be understood that the resistor 46

could instead be located internally of the housing 20 or within the body of the audio jack 44. The resistor has a resistance in the range: 1k Ω to 60k Ω ; preferably 45k Ω to 60k Ω ; more preferably 56k Ω , for reasons explained below.

[0025] The sensor 40 sits on a stepped disc-shaped sensor mount 50, with a sub-chamber 54 being defined between an upper surface of the mount 50 and the underside of the sensor 40. The sub-chamber 54 tapers in a stepped manner from the sensor 40 to the mount 50; in this example inwardly, narrowing towards the mount 50. In this embodiment, the mount 50 includes a central hole 56 through a bottom surface, and this defines a narrowest portion of the sub-chamber 54. It will be appreciated that other geometries for the sub-chamber 54 are also possible, including an opposite outward taper, or a smoother (non-stepped) taper, or indeed a constant cross-section.

[0026] A resilient pad 60 is positioned between the sensor mount 50 and the housing 20. More particularly, the resilient pad, which is in the form of a silicone disc 60 in this embodiment, sits snugly within the lower portion 26b of the interior chamber 26. The silicone disc 60 has a central recess 62 in which the underside of a narrowest part of the sensor mount 50 is retained. The resilient pad is typically made with 50 shore hardness silicone rubber. The resilient nature of the pad helps to isolate the sensor 40 from background vibrations transmitted to the housing 20, as explained in greater detail below. Primarily, however, the resilient pad 60 functions to act as a signal filter by restricting the piezoelectric sensor vibrations.

[0027] A probe 30 projects through the opening 27 and the internal cavity 29 of the spacer 28 and has an exposed tip portion 32 for insertion into a specimen 100 (typically into the trunk of a palm tree – see Fig. 8) and a base portion 34 connected to the acoustic sensor 40. In use, when the tip 32 is inserted into a specimen 100, vibrations within the specimen 100 will be transmitted to the probe 30 and will excite the piezoelectric sensor 40, converting kinetic energy of the vibrations to electrical energy in the form of output signals to be transmitted along the leads 42a, 42b as is known. Thus, if wood boring insects such as RPW larvae are active in the specimen 100, then that activity is transmitted as vibrations along the probe 30 to the acoustic sensor 40, which converts those vibrations to an output signal that will include a characteristic acoustic frequency indicative of that activity within the specimen. Because the piezoelectric sensor 40 is mounted on the resilient pad 60, the vibrations sensed by the sensor 40 are restricted to substantially just those transmitted through the probe 30; background mechanical vibrations such as induced through touching or scratching, which might otherwise be transmitted to the sensor 40 as a result of handling the detector 10, are filtered out, as are vibrations induced through movement of the trunk and leaves of the tree.

- [0028]** The spacer member 28 has a smaller diameter than the housing. When the detector 10 is attached to a specimen 100, the outermost end of the spacer member 28 comes into contact with the outside of the specimen 100, defining a separation distance S between the upper surface 25 of the housing 20 and the specimen 100, thereby ensuring that aside from the probe tip 32, there is only minimal contact of the detector with the specimen and accordingly only minimal transmission of vibrations along a path from the exterior of the specimen to the detector housing 20, particularly where, as illustrated, the spacer member 28 has a mouth 29b that defines a single annular point of contact at its rim. As such, predominantly only vibrations emanating from the interior of the specimen 100 will be transmitted to the acoustic sensor 40. The spacer member 28 also defines a depth of insertion D of the probe tip 32 into the specimen 100, thereby ensuring that the probe tip 32 is inserted to a consistent, repeatable depth. That way, one possible variable (the depth of insertion of the probe into the specimen) can be eliminated and readings taken from different positions or at different times can be compared uniformly.
- [0029]** The probe 30 is typically formed of a metallic material. Preferred and particularly suited materials include steel and alloys thereof, in particular stainless steel. In one embodiment, the probe 30 is made of stainless steel and has a thickness (diameter) in the range of 1-3 mm and a length in the range of 15-30 mm. In the illustrated embodiment, the probe 30 has a length of 27 mm and the separation distance S is 7.5 mm, with the depth of insertion D being 13.5 mm. The depth of insertion D will depend on the length of the probe 30 and on the separation distance S , and should be at least 8 mm to ensure that the probe tip 32 punches sufficiently far into the specimen for a reliable reading.
- [0030]** To ensure sufficient mechanical strength in the probe 30 and to prevent damage to the attached sensor 40 during insertion of the probe 30 into the specimen 100, the probe 30 is preferably securely attached to the opening 27 through the housing 20, for example by being bonded thereto.
- [0031]** A cover in the form of a resilient sheath 70 covers a majority of the housing surface. More particularly, the sheath 70 has a circular base 72 and a cylindrical sidewall 74 extending therefrom that respectively extend across the back and side surfaces of the housing 20. A lip portion 76 extends inwardly at the upper end of the sidewall 74 and partially covers the upper surface 25 of the housing 20. The resilient sheath 70, typically formed of silicone, which can be stretched over the housing 20 to form a snug cover, further helps to isolate the housing 20 and more particularly the acoustic sensor 40 within from external background noise, by absorbing incident vibrations.
- [0032]** Another embodiment of a wood boring insect detector 110 is shown in Figures 9 to 11B. The detector 110 of this embodiment is similar to the detector 10 described above,

and like parts are referenced by like numerals, but prefixed with '1'. Accordingly, the detector 110 comprises a substantially cylindrical housing 120 formed in two parts: a lower portion 122; and an upper portion 124, which fit together to define a hollow interior chamber 126. A cylindrical boss 165 with a blind hole 167 projects centrally into the interior chamber 126 from a base of the lower portion 122. An annular wall 169 surrounds the boss 165. The annular wall provides structural support for the lower portion 122, which helps to prevent distortion of the housing 120 when pressed to be inserted into a specimen. The housing 120 includes a central opening 127 connecting the interior chamber 126 axially to the exterior through an upper surface 125 of the housing. A channel 123 formed in the lower portion 122 connects the interior chamber 126 laterally to the exterior. A spacer member 128 projects from the upper surface 125 and surrounds the opening 127. The spacer member 128 is akin to the spacer member 28 of the detector 10 and likewise defines, in the illustrated embodiment, a horn-shaped internal cavity 129. The horn-shaped cavity 129 is akin to the horn-shaped cavity 29. Aside from the differences in detail as illustrated, the housing 120 is akin to the housing 20.

[0033] An acoustic sensor in the form of a substantially circular piezoelectric sensor 140 is mounted within the interior chamber 126. An electrical cable 142 comprising a pair of electrical leads (142a, 142b) extends from the sensor 140 through the channel 123 to an electrical connector (144). A resistor 146 may be connected in parallel between the leads, as described by reference to the sensor 40.

[0034] The sensor 140 sits on a stepped disc-shaped sensor mount 150, with a sub-chamber 154 being defined between an upper surface of the mount 150 and the underside of the sensor 140. In this embodiment, the mount 150 includes a central hole 156 through a bottom surface. It will be appreciated that other geometries for the sub-chamber 154 are also possible.

[0035] A resilient pad 160 is positioned between the sensor mount 150 and the housing 120. More particularly, the resilient pad, which is in the form of an annular cruciform silicone plug 160 in this embodiment, has a cylindrical lower portion 160b that sits snugly within the blind hole 167 of the lower housing portion 122. The silicone plug 160 has a central annular skirt 160c of substantially the same diameter as the boss 165. The silicone plug 160 also has a cylindrical upper portion 160a on which the sensor mount 150 is snugly retained by way of the central hole 156. The function of the resilient pad 160 is as described above in reference to the resilient pad 60.

[0036] A probe 130 projects through the opening 127 and the internal cavity 129 of the spacer 128 and has an exposed tip portion 132 for insertion into a specimen 100 and a base portion 134 connected to the acoustic sensor 140. The probe 130 is akin to the

probe 30 and the function and use of the detector 100 is akin to that of the detector 10 described above.

[0037] A cover in the form of a resilient sheath 170 covers a majority of the housing surface. This sheath 170 is akin to the resilient sheath 70 described above.

5 **[0038]** When connected to a suitable portable computing device such as a smartphone 80 programmed to receive the output signal from the acoustic sensor 40 (or 140) in the detector 10 (or 110) and to output an audio signal for listening by an operator, the detector 10/110 forms a wood boring insect detection kit. The portable computing device 80 may be configured to process the received output signal from the acoustic sensor 40/140 and to
10 output a modified audio signal for listening by an operator, for example through headphones 90 connected to the portable computing device 80 via a lead 92. Appropriate signal-processing software (e.g. a smartphone app) may be provided with the device (e.g. in the form of a download link). The processing in the portable computing device 80 may comprise at least one of amplifying and filtering the received output signal to produce the
15 audio signal.

[0039] The connection between the detector 10/110 and the portable computing device 80 is made by plugging the audio jack 44 into a compatible audio jack socket 82 on the portable computing device 80 in a known manner. In the case of a smartphone 80 operating under the Android™ operating system, the inclusion of a 56kΩ resistor 46 across
20 the output leads 42a, 42b from the sensor 40 provides the optimum signals for processing by the smartphone 80.

[0040] The audio jack connection is one convenient and common form of electrical connector for connecting the detector 10/110 to the associated portable computing device 80 (e.g. mobile phone), but it will be appreciated that there are numerous other ways in
25 which the electrical connection could be made, including other forms of physical connectors, or wireless signal transmission. Likewise, the connection between the portable computing device 80 and the associated headphones 90 may be made via a standard audio jack connection (and a splitter may be used so that both the headphone lead 92 and the connector 44 can be connected to a single audio port 82 on the device
30 80), or could be made by other known means, including wireless transmission. Moreover, a speaker could be used rather than headphones for listening to the output audio signal. However, headphones can be advantageous in passively (or actively) blocking out background sounds.

[0041] In use, an operator connects the detector 10/110 to an associated portable
35 computing device 80 and, in turn, to headphones 90. The detector 10/110 is placed on a specimen 100 to be tested, by inserting the probe 30/130 into the specimen and bringing

the spacer member 28/128 into contact with the outside of the specimen. Optionally, a strap (not shown) may be secured around the specimen 100 and the detector 10/110 to hold the detector 10/110 in place. The sensor 40/140 in the detector 10/110 is able to passively convert vibrations in the specimen to output signals for onward transmission to the portable computing device 80 over the connection. The portable computing device 80 thus receives the output signal from the audio sensor 40/140, processes that output signal and outputs an audio signal over the connection to the headphones 90 to be listened to by an operator. The operator listens to the audio signal and decides, based on experience, whether that audio signal includes a characteristic sound (frequency) indicative of the presence of wood boring insect activity within the specimen. If so, the operator can mark the specimen 100 as infested.

[0042] Because it has been recognised that the human auditory cortex has a working memory of approximately 5 minutes during which time recently heard sounds are retained, the inventors have determined that by providing for the operator to listen to a sound recording containing a characteristic sound (e.g. of fibres being crunched at the characteristic frequency for a particular larva) within that time frame, the operator is effectively 'primed' to recognise that characteristic sound within the subsequently heard audio signal, thereby increasing the chances of correctly identifying the presence (or absence) of an insect within the specimen. Thus, the operator can listen to a 'pure' sound recording of the insect activity to be identified immediately prior to listening to the output signal from the detector 10. In one embodiment, the smartphone app through which the method is controlled may include the option to listen to a clear crunching sound track if, having listened to the sounds through the detector 10/110, the operator is not sufficiently sure to take a decision as to whether the sounds are characteristic of the presence of an insect within the specimen. This feature helps the operator to sharpen detection by having a template in the working memory. The 'pure' sound recording may have been made under controlled conditions, such as in a laboratory setting, to ensure that it is substantially free from unwanted background noise. It may also have been subject to signal processing for the same purpose. Such 'pure' recordings therefore have a minimal amount of noise (as opposed to useful signal) and are typically stored in the device 80 (e.g. in a non-volatile memory), and can be accessed for playback for example through user-selection within an app. The output signals from the detector 10/110 may also be stored to memory in the device 80 for subsequent recall and analysis. It will be understood that the sound recordings (both the 'pure' recording and recordings made in the field by the detector) may alternatively be stored remotely.

[0043] Overall, the configuration of the housing 20/120 and the spacer member 28/128, including the internal cavities/chambers 26/126, 29/129, 54/154, the mount 50/150 and the resilient pad 60/160, as well as the outer sheath 70/170 provide for particularly good acoustic properties; providing physical elements that filter out much of the background noise so that substantially only noises emanating from within the specimen 100 (i.e. the characteristic crunching sound produced by the insects chewing on fibres in the specimen) are picked up by the acoustic sensor 40/140 and therefore, output to be heard by an operator of the detector 10/110. In this regard, the sub-chamber 54/154, and particularly the tapering volume defined by it has been found to improve the acoustic properties by acting as a physical filter. The sub-chamber 54/154 is configured to help amplify piezoelectric sensor vibrations by captivating acoustic signals coming through the probe 30/130 inside the internal cavities/chambers 26/126, 29/129, 54/154, and allowing the piezoelectric sensor 40/140 to vibrate relatively freely, thereby improving the amplitude of the signals and the sensitivity of the sensor 40/140. This is at least in part due to the vibration amplification effect in a cavity of air – here defined by the internal surfaces of the internal cavities/chambers 26/126, 29/129, 54/154 – with vibrations in the cavity arriving from the probe 30/130 being reflected internally. Also, the horn-shaped cavity 29/129 acts like the cochlear and thus further helps to filter out unwanted background noise, due to the physical shape. Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of them mean “including but not limited to”, and they are not intended to (and do not) exclude other moieties, additives, components, integers or steps. Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

[0044] Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

[0045] The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

CLAIMS

1. A wood boring insect detector comprising:
 - a housing defining a hollow interior chamber and including an opening connecting
 - 5 the interior chamber to the exterior;
 - a spacer member surrounding the opening and defining an internal cavity;
 - an acoustic sensor mounted within the interior chamber;
 - a probe projecting through the opening and the internal cavity of the spacer and
 - having an exposed tip portion for insertion into a specimen and a base portion connected
 - 10 to the acoustic sensor, wherein the spacer member defines a separation between the
 - housing and the specimen and a depth of insertion of the probe tip into the specimen;
 - wherein when the tip portion is inserted into a specimen, wood boring insect activity
 - within the specimen is transmitted as vibrations along the probe to the acoustic sensor,
 - which converts those vibrations to an output signal of a characteristic acoustic frequency
 - 15 indicative of the presence of wood boring insect activity within the specimen.
2. The detector of claim 1, further comprising a sensor mount within the interior chamber, a sub-chamber being defined between the mount and the sensor.
3. The detector of claim 2, wherein the sub-chamber tapers from the sensor to the mount.
- 20 4. The detector of claim 2 or claim 3, further comprising a resilient pad between the sensor mount and the housing.
5. The detector of any preceding claim, wherein the internal cavity of the spacer is horn-shaped, tapering outwardly from a relatively narrow channel at the opening to a relatively wide mouth towards the tip portion of the probe.
- 25 6. The detector of any preceding claim, wherein the sensor is a piezoelectric sensor.
7. The detector of any preceding claim, further comprising a resistor connected in parallel with the sensor, wherein the resistor has a resistance in the range: 1k Ω to 60k Ω ; preferably 45k Ω to 60k Ω ; more preferably 56k Ω .
8. The detector of any preceding claim, wherein the probe is metal.
- 30 9. The detector of any preceding claim, wherein the housing is cylindrical.
10. The detector of any preceding claim, further comprising a resilient sheath covering at least a majority of the housing surface.

11. The detector of any preceding claim, further comprising an electrical output connector to form an electrical connection with a mating electrical input connection of a portable computing device for the transmittal of the output signal to the portable computing device.
- 5 12. The detector of claim 11, wherein the electrical output connector comprises an audio jack.
13. The detector of any preceding claim, for use in detecting red palm weevil larvae, and wherein the specimen comprises a palm tree.
14. A wood boring insect detection kit comprising:
- 10 the detector of any preceding claim; and
- a portable computing device configured to receive the output signal from the acoustic sensor in the detector and to output an audio signal for listening by an operator.
15. A method of detecting wood boring insects, comprising:
- 15 using a detector according to any of claims 1 to 13, inserting the probe into a specimen bringing the spacer into contact with the specimen to ensure the probe is inserted to the correct depth;
- forming a communication connection between the detector and a portable computing device, whereby the portable computing device receives the output signal from the audio sensor;
- 20 processing the output signal in the portable computing device and outputting an audio signal for listening by an operator; and
- the operator listening to the audio signal and deciding whether that signal includes a characteristic frequency indicative of the presence of wood boring insect activity within the specimen.
- 25 16. The method of claim 15, wherein the processing in the portable computing device comprises at least one of amplifying and filtering the received output signal to produce the audio signal.
17. The method of claim 15 or claim 16, further comprising:
- 30 within 5 minutes prior to the operator listening to the audio signal, first listening to a recorded audio signal known to have been recorded in the presence of wood boring insect activity.

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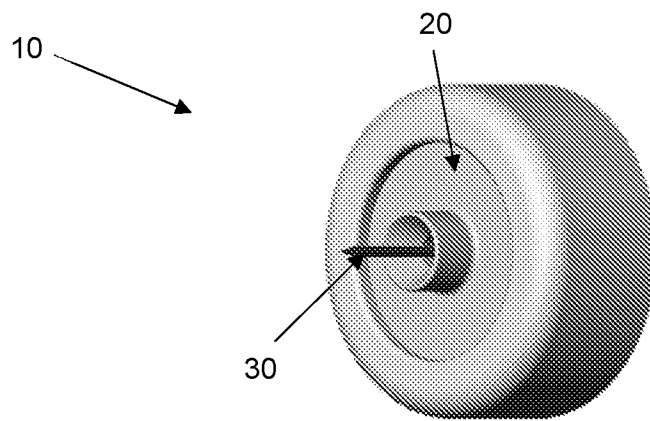


Fig. 1

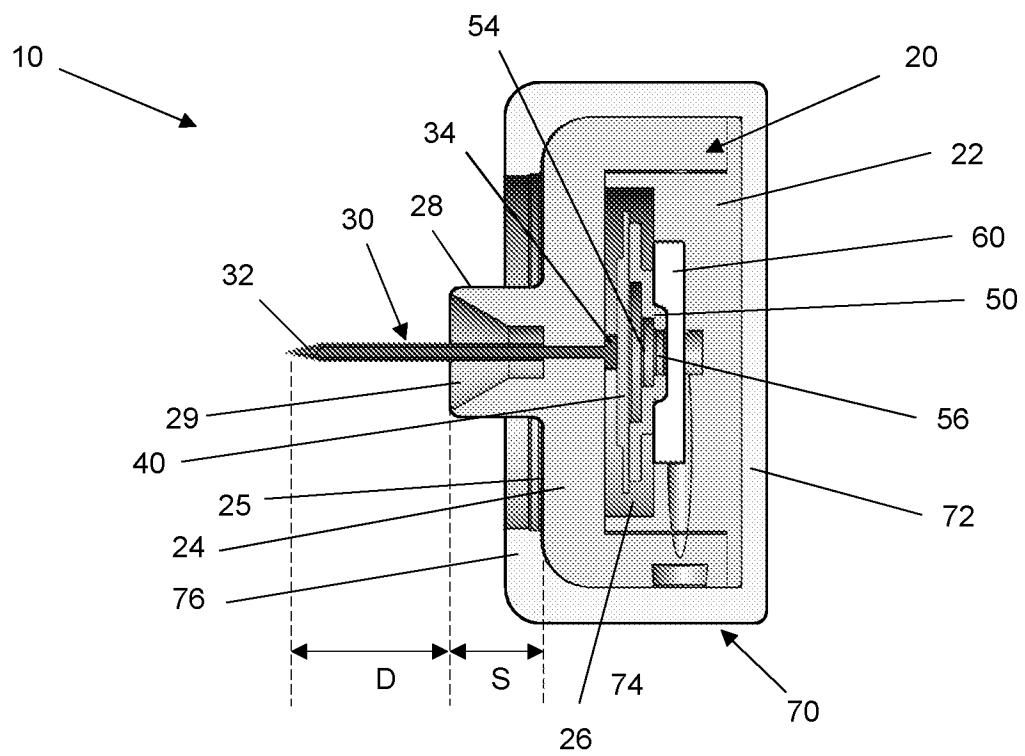


Fig. 2

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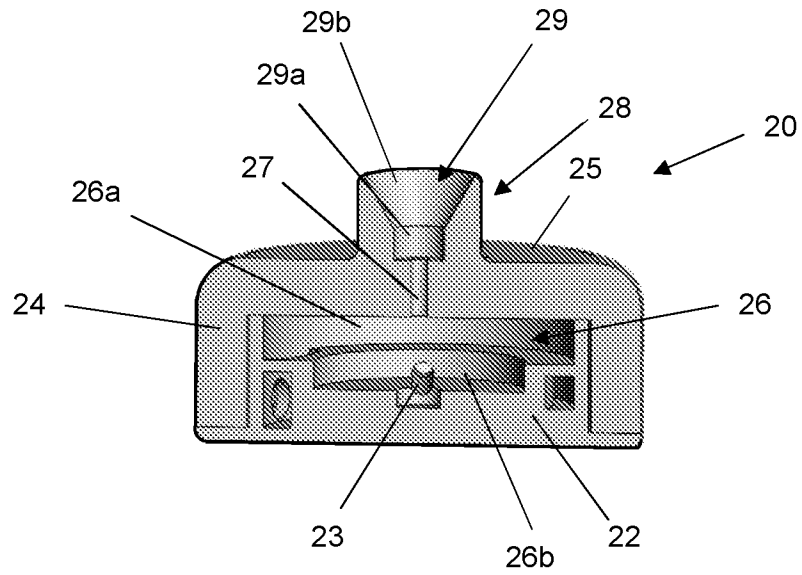


Fig. 3

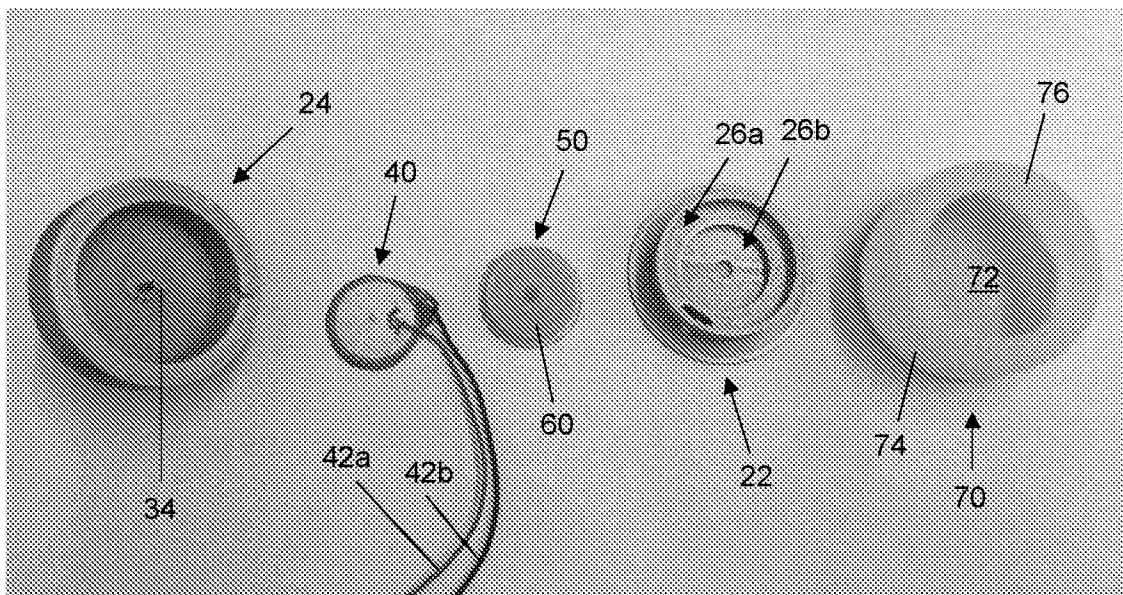


Fig. 4

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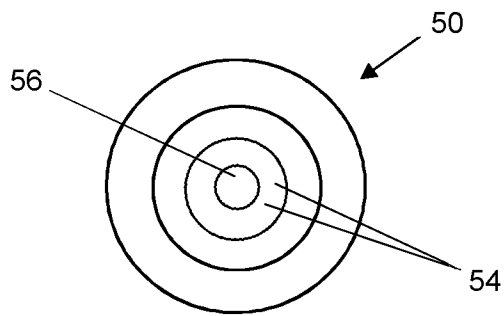


Fig. 5

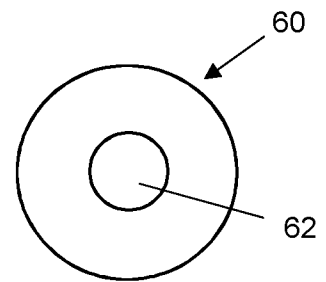


Fig. 6

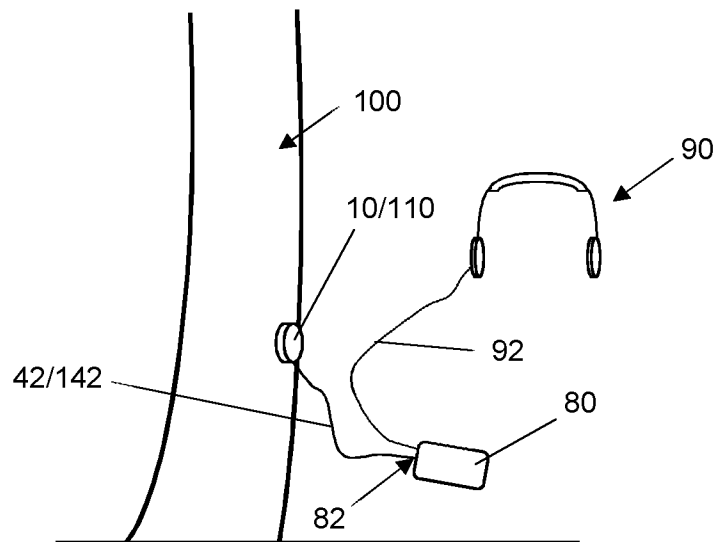


Fig. 8

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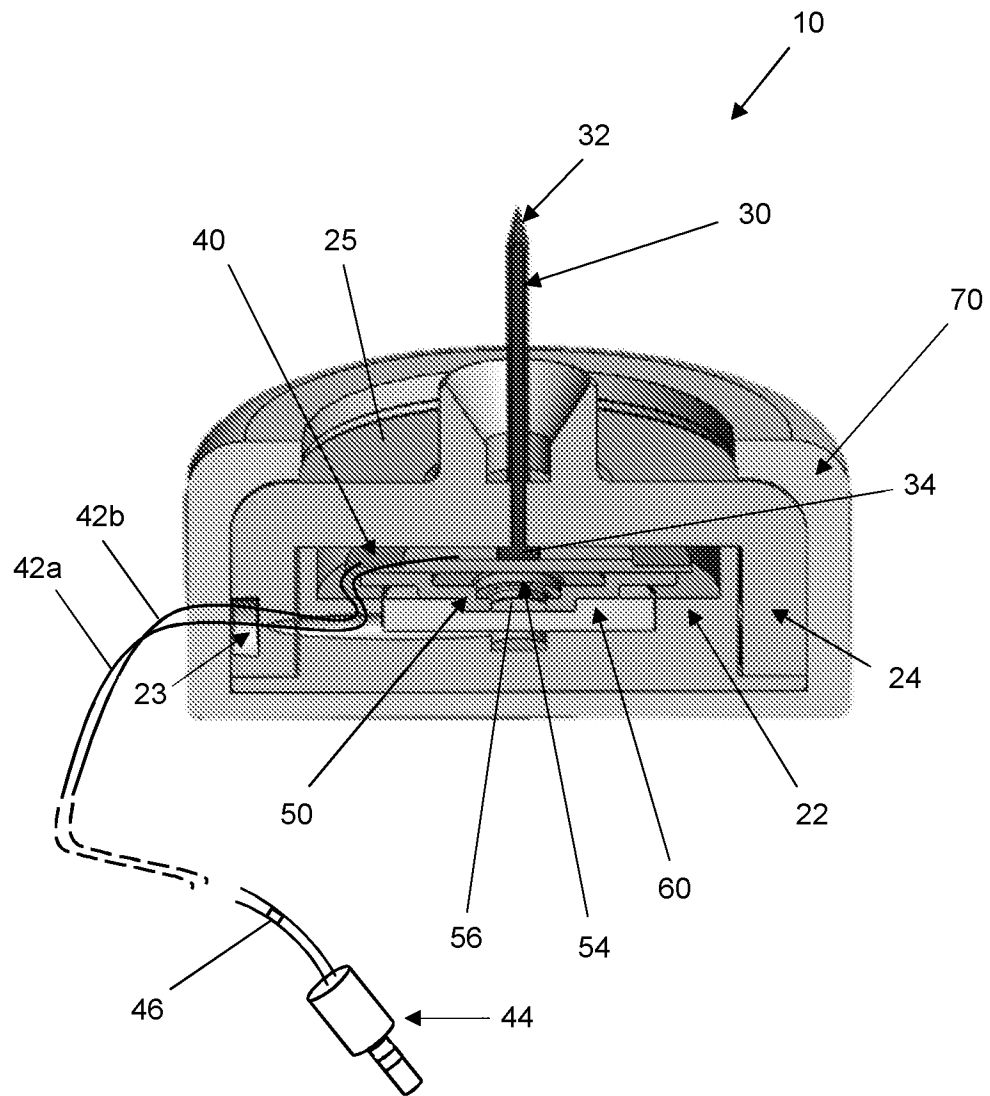


Fig. 7

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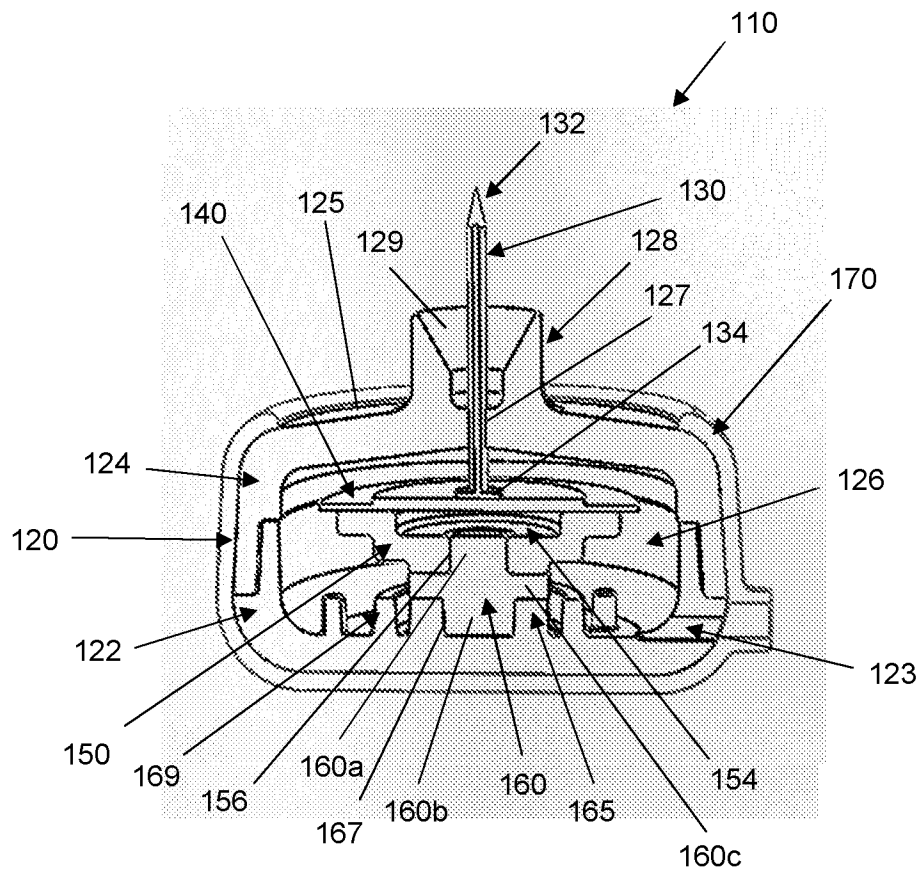


Fig. 9

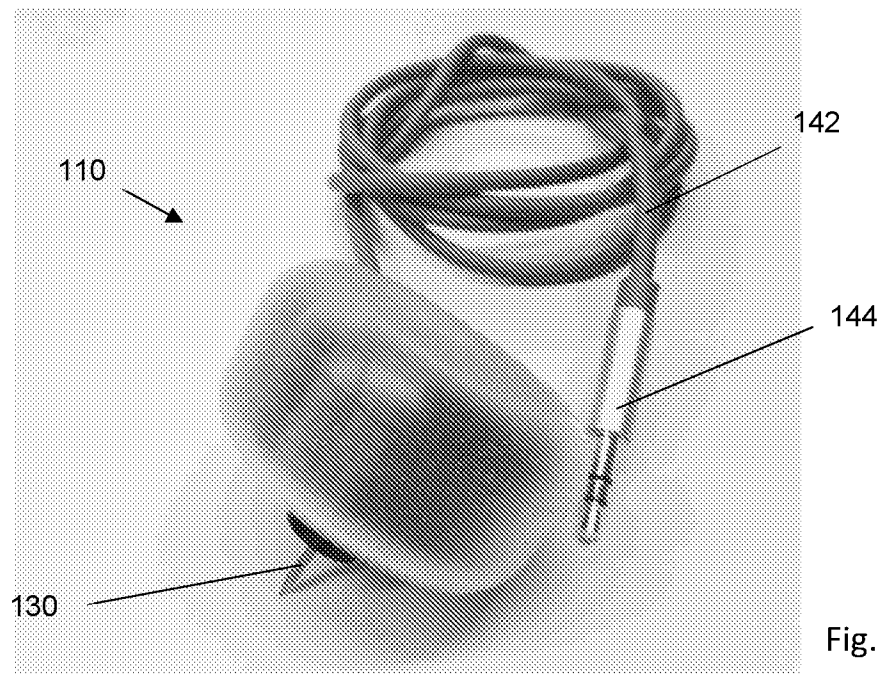


Fig. 10

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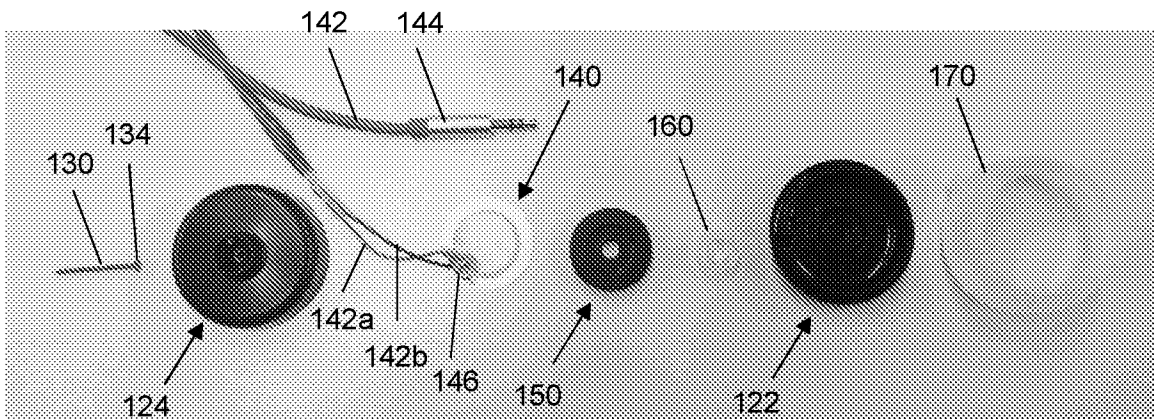


Fig. 11A

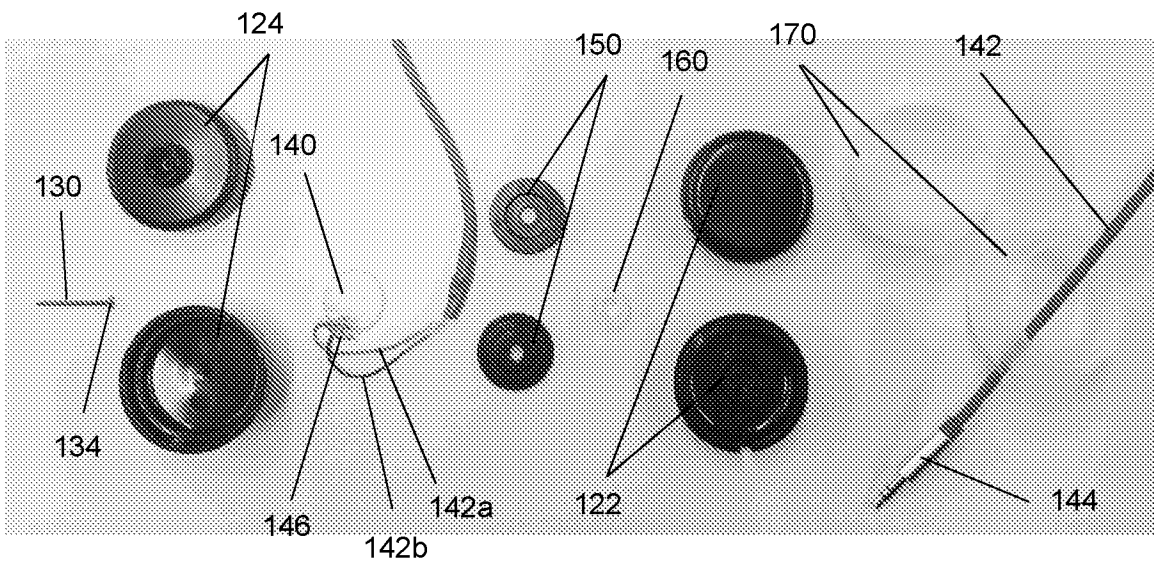


Fig. 11B

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2019/053190

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N29/14 G01N29/24 G01N29/32 A01M1/02 G01N29/44
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)

G01N A01M

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	US 2006/028345 A1 (LEE PENG [US]) 9 February 2006 (2006-02-09) the whole document	1-4,9-17
X	US 2004/107773 A1 (DUNEGAN HAROLD L [US]) 10 June 2004 (2004-06-10) the whole document	2,4-17
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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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

22 January 2020

Date of mailing of the international search report

31/01/2020

Name and mailing address of the ISA/

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Authorized officer

Roetsch, Patrice

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2019/053190

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SIRIWARDENA K A P ET AL: "Portable acoustic device for detection of coconut palms infested by Rynchophorus ferrugineus (Coleoptera: Curculionidae)", CROP PROTECTION, ELSEVIER SCIENCE, GB, vol. 29, no. 1, 1 January 2010 (2010-01-01), pages 25-29, XP026748014, ISSN: 0261-2194, DOI: 10.1016/J.CROPRO.2009.09.002 [retrieved on 2009-10-13] paragraph [0002]; figures 1-3 -----	1-17

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2019/053190

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 2005199065 A1	15-09-2005
