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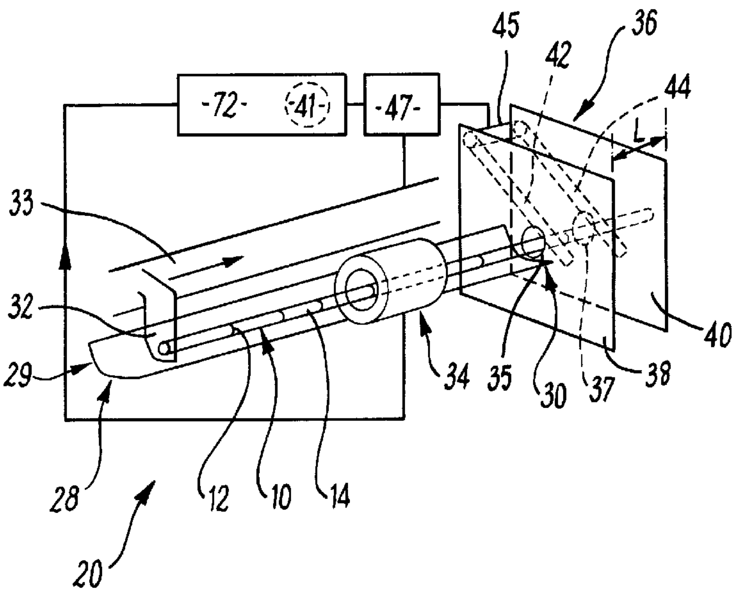

FIG. 4

(57) Abstract: A method of detecting the presence of a node (12) within a stem (10) of a plant, the method comprising making two measurements of a component of the electrical impedance of the stem (10), wherein a first measurement is made at a first location along the stem (10) and a second measurement is made at a second location along the stem (10), comparing the first measured component of the electrical impedance and the second measured component of the electrical impedance to produce a resultant output, and analysing the resultant output in order to determine the presence of a node or otherwise at the first location or the second location.

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Sensing Method and Apparatus for Detecting Plant Nodes

The present invention relates to a method of sensing the presence of a node in a stem of plant, and a sensor apparatus.

Plants of the Gramineae/Poaceae family, such as sugar cane, bamboo and elephant grass, usually grow in the form of a stem. Each stem comprises a plurality of nodes (also known as plené or bola) separated by internodal portions. The node comprises the bud (or gemma) of the plant, which may be planted to yield a new plant.

Due to the fact that sugar cane is an important commercial crop, especially due to its significance in the production of the renewable fuel ethanol, it is desirable to maximise the efficiency of the agricultural processes surrounding sugar cane production. The traditional planting process of sugar cane involves harvesting a portion of the crop, cutting the harvested stems into segments of approximately 20-50cm in length (so that 2-4 nodes are present in each stem segment (also known as a sett)), and then replanting each segment horizontally. It is necessary to cut the stems since, due to a process known as apical dominance, it is likely that only one bud per section of stem will germinate. The segments are cut so as to comprise 2-4 nodes for two main reasons: first, not every bud germinates; and secondly, the buds only germinate under specific environmental conditions. The stem segments aid in providing their bud with these conditions. The stem segment provides nutrients and moisture for the germinated bud, as well as insulation against various detrimental climatic conditions.

Current machines used to cut sugar cane segments cut the stem at positions which are not determined in relation to characteristics of the stem itself, but purely on the requirement that the segments are of a particular length. Although this plantation technique is still in use, it is relatively inefficient for various reasons. First, segments cut by current machines each comprise a plurality of nodes. Each of these nodes is theoretically capable of geminating, but as only one node does so (due to apical dominance), the non-germinated nodes are wasted. Secondly, cutting larger segments than are necessary requires that for a given number of planted segments, more cane from the crop must be used for re-planting purposes, hence reducing the crop yield. Thirdly, the internodal portions of the segments and hence any product which may have been produced from them is wasted. Finally, cane segments which are larger than necessary are more difficult to store and transport. This is because larger cane segments take up more space than smaller cane segments and also weigh more. The storage and transport of cane segments will be of particular concern if it is desired to distribute and sell processed cane segments.

It has been found that, when treated with certain fertilizers and other compounds before planting, germination of a bud is possible from a short stem section having a single node. This process is described in WO 2009/000398, WO 2009/000399, WO 2009/000400, WO 2009/000401 and WO 2009/000402.

Due to the fact that employing people to cut each segment would be very labour intensive, it is desirable to provide an automated method to select and cut stem segments with desired characteristics, particularly segments comprising one node, without damage. Additionally, the automated method may select and discard stem segments having an undesired characteristic, such as the presence of a disease, pest, or rot, so as to avoid the replanting of segments that are unlikely to have a viable bud.

Previous methods of trying to locate the position of the nodes have involved the use of optical sensors or MRI (magnetic resonance imaging) sensors. Optical sensors have proved ineffective for various reasons. The sugar cane may be covered by leaves or detritus which obscures an optical sensor's view of the stem and hence the nodes. In addition, some optical methods require image processing, the complexity of which makes the method prohibitive at the high speeds at which the machine is envisaged to operate in order to make it cost effective. MRI methods suffer from similar image processing limitations, which combined with their high cost make them undesirable.

It is desirable to provide a sensing method which overcomes a problem associated with the prior art.

According to a first aspect of the present invention there is provided a method of detecting the presence of a node within a stem of a plant, the method comprising: making two measurements of a component of the electrical impedance of the stem, wherein a first measurement is made at a first location along the stem and a second measurement is made at a second location along the stem; comparing the first measured component of the electrical impedance and the second measured component of the electrical impedance to produce a resultant output; and analysing the resultant output in order to determine the presence of a node or otherwise at the first location or the second location.

The sensor apparatus according to the present invention provides a low cost and effective way of detecting the location of nodes within a plant stem. Information concerning the location of the nodes may be supplied to a control system of a plant cutting machine such that sections of the plant stem which each contain a sensed node can be cut from the remaining plant stem.

In some embodiments the component of the electrical impedance may be capacitance, inductance or resistance.

The first and second measurements may be simultaneous.

In some embodiments, comparing the first measured component and the second measured component may comprise determining the difference between the first measured component and the second measured component.

The first measurement may part of a set of first measurements, each member of the set of first measurements being measured at a different time; and the second measurement may be part of a set of second measurements, each member of the set of second measurements being measured at a different time; and wherein the resultant output may be part of a set of resultant outputs, the set of resultant outputs being analysed in order to determine the presence of a node or otherwise.

The first measurement may be part of a set of first measurements, each member of the set of first measurements being measured at a different location along the stem; and
the second measurement may be part of a set of second measurements, each member of the set of second measurements being measured at a different location along the stem; and wherein the resultant output may be part of a set of resultant outputs, the set of resultant outputs being analysed in order to determine the presence of a node or otherwise.

In some embodiments, the first location may be adjacent the second location.

In some embodiments, the component of electrical impedance may be capacitance or inductance, measured using an electrical property sensor which does not contact the stem.

In some embodiments, the component of impedance may measured by an electrical property sensor, the electrical property sensor having a first part and a second part and wherein the first measurement is made by the first part and the second measurement is made by the second part.

According to a second aspect of the invention there is provided a method of detecting the presence of a node within a stem of a plant, the method comprising: measuring the inductance or resistance of a location along the stem; and analysing the measured inductance or resistance so as to determine the presence of a node or otherwise at that location. In some embodiments, the inductance of the stem is measured using an electrical property sensor which does not contact the stem.

In some embodiments the method further comprises generating a signal to indicate the presence of a node.

According to a third aspect of the invention there is provided a plant stem cutting method, wherein the generated signal is supplied to a control system of a cutting machine, the control system actuates a cutting mechanism of the cutting machine in response to the signal; and the cutting mechanism cuts a portion of the stem which contains the node from the remainder of the stem.

According to a fourth aspect of the invention, there is provided a sensor apparatus suitable for measuring a component of the electrical impedance of a stem of a plant, the sensor apparatus comprising an electrical property sensor and a signal analyser;
wherein the electrical property sensor is configured to make two measurements of the component of the electrical impedance of stem, a first measurement being made at a first location along the stem and a second measurement being made at a second location along the stem; and wherein the signal analyser is configured to compare the first and second measurements to produce a resultant output, and to analyse the resultant output in order to determine the presence of a node or otherwise at the first location or the second location.

The component of the electrical impedance may be capacitance, inductance or resistance.

In some embodiments, the signal analyser may be configured to determine the difference between the first measurement and the second measurement.

In some embodiments, the first measurement may be part of a set of first measurements, each member of the set of first measurements being measured at a different time; the second measurement may be part of a set of second measurements, each member of the set of second measurements being measured at a different time; and wherein the resultant output may be part of a set of resultant outputs, the signal analyser being configured to analyse the resultant output set in order to determine the presence of a node or otherwise.

In some embodiments, the first measurement may be part of a set of first measurements, each member of the set of first measurements being measured at a different location along the stem; the second measurement may be part of a set of second measurements, each member of the set of second measurements being measured at a different location along the stem; and wherein the resultant output may be part of a set of resultant outputs, the signal analyser being configured to analyse the resultant output set in order to determine the presence of a node or otherwise.

The first location may be adjacent the second location.

In some embodiments, the component of the electrical impedance is resistance, and the electrical property sensor comprises at least two electrodes which are configured to contact the stem.

In some embodiments, the component of electrical impedance may be capacitance and the electrical property sensor may comprise at least two electrodes.

The sensor apparatus may comprise a common electrode, a second electrode and a third electrode, the electrical property sensor being configured make the first measurement between the common electrode and the second electrode; and make the second measurement between the common electrode and the third electrode.

In some embodiments, the component of electrical impedance may be inductance, and the electrical property sensor may comprise at least two coils. The coils may be disposed upon a member made from magnetic material which forms a discontinuous loop, the discontinuous loop being configured to receive the stem within or adjacent to the discontinuity of the discontinuous loop.

The electrical property sensor may comprise a first part configured to make the first measurement, and a second part configured to make a second measurement.

According to a fifth aspect of the invention there is provided a sensor apparatus suitable for measuring the resistance or inductance of a stem of a plant, the sensor apparatus comprising an electrical property sensor and a signal analyser, the electrical property sensor being configured to measure the resistance or inductance of a location along the stem, wherein the signal analyser is configured to analyse an output of the electrical property sensor indicative of the measured resistance or inductance and determine if a node is present at that location.

The plant of any of the aspects of the invention may be a plant from the Gramineae or Poaceae family.

According to a sixth aspect of the invention, there is provided a plant stem cutting machine comprising a sensor apparatus according to the fourth and fifth aspects of the invention, wherein the signal analyser is additionally configured to generate a signal indicative of the presence of a node, the plant stem cutting machine additionally comprising a control system and a cutting mechanism, wherein the generated signal is supplied to the control system, and wherein the control system is configured to actuate the cutting mechanism in response to the signal such that the cutting mechanism cuts a portion of the stem which contains the node from the remainder of the stem.

Figure 1 shows part of a sugar cane stem;
Figure 2 shows sections of sugar cane stem which have been cut from a sugar cane stem by a cutting machine according to an embodiment of invention;
Figure 3 shows the ends of several sugar cane stems which are obscured by husk;
Figure 4 shows schematically a cutting machine according to an embodiment of the invention,
Figure 5 shows schematically a first sensor according to an embodiment of the invention;
Figure 6 shows schematically a second sensor according to an embodiment of the invention;
Figure 7 is a cross-sectional view of the sensor shown in figure 5;
Figure 8 is a cross-sectional view of the sensor shown in figure 6;
Figure 9 is a graph of absolute capacitance against time measured using the sensor shown in figures 6 and 8;
Figure 10 is a graph of differential capacitance against time measured using the sensor shown in figures 6 and 8;
Figure 11 is a graph of absolute capacitance against time measured using the sensor shown in figures 7 and 9;

Figure 12 is a graph of differential capacitance against time measured using the sensor shown in figures 7 and 9; and

Figure 13 shows schematically a third sensor according to an embodiment of the invention; and

Figure 14 shows a fourth sensor according to an embodiment of the invention.

Figure 1 shows a stem 10 of sugar cane. The stem 10 comprises a plurality of nodes 12 (also known as plené or bola) separated by internodal portions 14. The internodal portions 14 may have different lengths. It is desirable to be able to cut the stem 10 into small sections 16 (or sett), as shown in figure 2, which each contain a single node 12. The sections 16 may for example be approximately 50mm long, with the node 12 being located centrally. This helps to prevent the node 12 and any bud which germinates from it from detrimental environmental conditions. For example, in dry conditions, it helps to prevent the node 12 from drying out. However, it will be appreciated that the sections 16 may be of any appropriate length and that the node 12 may be located at any appropriate position within each section 16. Once the sections 16 have been cut, they may be treated with an agrochemical or anti-desiccant or the like. The sections may then be stored, transported to a different location and/or planted.

In order to cut the sections 16 such that each one contains a node 12, it is necessary to detect the locations of the nodes 12 within the stem 10. Various methods have been suggested in the prior art in order to try to accomplish this. These include the use of pressure sensors, optical sensors and MRI (magnetic resonance imaging sensors). A known pressure sensor measures the variation in thickness of the stem 10 as the stem 10 passes through it. Since the nodes 12 of the stem 10 are generally of greater thickness compared to the internodal portions 14, the portions of the stem 10 which are of greatest thickness tend to be the nodes 12. However, this process is problematic in that the stems 10 may be covered in leaves (also known as husk) or other detritus which causes a variation in the thickness measured by the sensor which is not representative of a variation in the thickness of the stem 10. A variety of optical sensors are also known. Some measure an optical property of the stem directly, for example reflectivity, whereas others rely on image processing techniques. Both types of optical sensor have a similar disadvantage in that in order to detect nodes 12 within the stem 10, they must have an unobstructed view of the stem 10. As previously discussed, it is common that the stem 10 is covered in husk, soil and detritus. This is shown clearly in figure 3 in which husk 18 obscures the view of the stem 10. Furthermore, the optical sensors which rely on image processing techniques may be sub-optimal in that they may be very computationally expensive, and as such too slow to cope with the high speeds of a cutting machine. Known MRI sensors require processing which is equally computationally expensive as that of the image processing optical sensors. In addition, MRI sensors are very financially expensive.

An embodiment of the present invention uses an electrical property sensor to measure an electrical property of the stem 10. The processing required to analyse the output of the electrical property sensor may be much less than of MRI and optical image processing sensors. Consequently, the sensor of an embodiment of the present invention is capable of being used with cutting machines which operate at greater speeds. Furthermore, the electrical property sensor may have a relatively low cost compared to an MRI sensor.

Figure 4 shows a schematic view of a cutting machine 20 according to an embodiment of the invention. A cutting conduit 28 holds a stem 10. The stem 10 may be placed in the cutting conduit 28 by any suitable means, for example a conveyor belt (not shown). The cutting conduit 28 is longitudinal in nature and is long enough to accommodate the stem 10. The cutting conduit 28 has an upstream end 29 and a downstream end 30.

A cane grabber 32 lies at least partially within the conduit 28. The cane grabber 32 is actuated by an actuator 33. When a stem 10 is placed into the cutting conduit 28, the actuator 33 moves the cane grabber 32 out of the way of the inserted stem 10 by moving the cane grabber 32 towards the upstream end 29 of the conduit. In this way, the cane grabber 32 does not obstruct the insertion of the stem 10 into the conduit 28. Once the stem 10 has been inserted into the conduit 28, the actuator 33 moves the cane grabber 32 such that it moves within the conduit 28 towards the downstream end 30 of the conduit. The cane grabber 32 contacts the stem 10 and moves the stem 10 along the conduit 28 and through an aperture 35 adjacent the downstream end 30 of the conduit.

Any suitable means may be used to move the stem 10 through the conduit 28.

As the stem 10 travels along the conduit 28, it passes through an electrical property sensor 34, and then into a cutting mechanism 36. The cutting mechanism 36 comprises two parallel plates 38, 40. The distance L between the parallel plates 28, 40 corresponds to the desired length of cut stem sections 16 (see figure 2). Each plate has an aperture through its centre (35 and 37 respectively) which is aligned with the conduit 28 such that a stem 10 will pass from the conduit 28 into the apertures 35,37. Adjacent each plate 38, 40 are blades 42, 44. In their rest position (as seen in figure 4) the blades 42, 44 are adjacent their respective apertures such that they do not obstruct the passage of the stem 10 through the apertures. The blades 42, 44 may be actuated such that they pass over the apertures, thereby cutting any portion of stem 10 which is in their path. The blades 42, 44 are actuated by an actuator 45 in response to a control signal. The control signal is supplied to the actuator 45 from a cutting machine control system 47 in response to output from the electrical property sensor 34. In this way, two cuts are made in the stem 10 simultaneously, such that the material between the cuts forms a section 16 (as seen in figure 2) which contains a node 12.

The electrical property sensor 34 detects an electrical property of a location along the stem 10 as the stem passes the electrical property sensor. The stem 10 may, depending on the nature of the electrical property to be sensed and hence the nature of the electrical property sensor 34, pass through a portion of the electrical property sensor (as shown in figure 4) or pass adjacent to it. The distance between the electrical property sensor 34 and stem 10 may be any appropriate distance, but should be close enough that the electrical property sensor 34 can detect a difference between an electrical property of a node 12 and an internodal portion 14.

The electrical property sensor 34 outputs a signal indicative of the measured electrical property to a signal analyser 72. The signal analyser is configured to analyse the output of the electrical property sensor 34 to determine whether a node is present. The electrical property sensor 34 and the signal analyser 72 may together be considered to comprise a sensor apparatus.

The signal analyser 72 generates a signal which is indicative of the presence of a node. The signal is supplied to the cutting machine control system 47, which actuates the blades 42,44 once the node is between the blades.

In some embodiments the signal analyser 72 may include a signal processor 41 which may provide analogue filtering and/or digital signal processing (such as a Fourier transform or cross-correlation function). Analogue filtering or digital signal processing may be applied to the output of the electrical property sensor 34, and/or may be applied to the generated signal which is indicative of the presence of a node.

The cutting machine control system 47 synchronises the grabber actuator 33, electrical property sensor 34 and blade actuator 45 such that when a node 12 is detected by the electrical property sensor 34 and signal analyser 72, the blades 42, 44 are subsequently actuated so as to cut a section 16 of stem 10 which contains the sensed node 12. The blades 42, 44 are actuated when the node has passed from the electrical property sensor 34 to the cutting mechanism 36.

The electrical property which is measured by the electrical property sensor 34 in the embodiment shown in figure 4 (and also figures 5 and 6) is capacitance. Capacitance is a component of electrical impedance (hereinafter referred to as impedance). Impedance is a measure of the opposition that something provides to an alternating current passing through it. Impedance is the sum of resistance and reactance. Resistance is a measure of the opposition of something to non-oscillating current passing through it. Reactance is a measure of the opposition of something to an alternating current passing through it, due to the presence of electric or magnetic fields set up by the alternating current. Reactance comprises capacitance and inductance. Capacitance is a measure of the opposition to the current due to accumulated charge, and inductance is a measure of the opposition to the current due to the rate of change of the current. Inductance and capacitance are components of impedance.

The electrical property sensor may measure any electrical property which is a component of impedance. This may for example include capacitance, inductance or resistance. It is possible to locate the position of the nodes 12 using these electrical properties because the nodes 12 and internodal portions 14 have different electrical properties, due to a higher fibre content of the nodes 12 relative to the internodal portions 14, and a higher water content in the internodal portions 14 compared to the nodes 12.

The operation and configuration of the electrical property sensor will be dependant upon which electrical property it is detecting. For example, a resistance sensor may contact the stem 10, whereas capacitance and inductance may be measured by electrodes and coils respectively which do not contact the stem 10. It will be appreciated that a stem 10 may inadvertently contact an electrode or coil in use. However, this is incidental and not necessary for the functioning of the sensor.

In some embodiments the electrodes or coils may be spaced from the stem 10 (i.e. separated from the region which is expected to be occupied by the stem in use). In other embodiments a non-conducting intermediate member may be located between the electrodes or coils and the region which is expected to be occupied by the stem in use. In some embodiments it is beneficial that the electrodes or coils do not contact the stem 10 because this minimises any wear to the electrodes or coils. In some circumstances, wear of the electrodes or coils may result in the electrical property sensor 34 failing and hence needing to be replaced.

The electrical property sensor 34 of figure 4 is shown in more detail in figure 5. The electrical property sensor 34 is a capacitance sensor. The electrical property sensor may for example be capable of detecting capacitance changes in the femtoFarad region.

The embodiment of capacitance sensor shown in figure 5 comprises three co-axial adjacent ring electrodes 50, 52, 54 which are disposed upon a non-conducting tube 56 (the tube may for example be made from plastic). In use, a cane stem 10 passes through the plastic tube 56, the tube 56 acting as a conduit. In one embodiment of the invention, the plastic tube 56 has a diameter of 50mm and the ring electrodes are made of 10mm wide copper tape, each ring being spaced from its adjacent one by approximately 3.5mm. The electrodes may be made from any appropriate conductive material and may be any appropriate size or spacing.

The tube 56, may be of any appropriate diameter. The tube 56 should be large enough to receive the largest expected diameter of cane stem and small enough such that differences in the capacitance of the cane stem (as a function of the presence of nodes) can be measured as the cane stem 12 passes through the tube 56. Making the tube 56 diameter smaller maximises the proportion of volume between the electrodes which the cane stem occupies when it is within the tube 56. The greater the proportion of the volume of the tube between the electrodes that the stem occupies, the more sensitive the capacitance between the electrodes is to variations in an electrical property (for example permittivity) of the stem. This will enable the electrical property sensor to more accurately determine the presence of a node.

It is possible to measure the capacitance between any two electrodes. For example, in the embodiment shown in figure 5, the capacitance may be measured between the central electrode 52 and either of the outer electrodes 50, 54. Such a measurement of capacitance is referred to as absolute capacitance.

Another way of measuring the capacitance of the cane stem 10 is to measure a differential capacitance. In one example, a first capacitance measurement is taken between the centre electrode 52 and a first outer electrode 50, and a second capacitance measurement is taken between the centre electrode 52 and a second outer electrode 54. These measurements are then compared in order to produce a resultant output. The resultant output may be referred to as the differential capacitance. The comparison of the measurements may for example comprise subtracting one measurement from the other, although any appropriate comparison may be made.

The first and second measurements may be taken between two separate electrode pairs, instead of using a common centre electrode 52. Again, the resultant output may be referred to as the differential capacitance.

The first electrode pair may be thought of as a first part of the electrical property sensor, and the second electrode pair may be thought of as a second part of the electrical property sensor. In the alternative embodiment described above which comprises the centre electrode 52, the first outer electrode 50 and the second outer electrode 54, the centre electrode and first outer electrode may be though of as the first part of the electrical property sensor, and the centre electrode and the second electrode may be thought of as the second part of the electrical property sensor.

At any given time, the first part of the electrical property sensor 34 may measure capacitance at a first location along the stem 10, and the second part of the electrical property sensor 34 may measure capacitance at a second location along the stem.

In an alternative embodiment the first and second parts of the electrical property sensor may be configured to measure a component of impendence other than capacitance (e.g. inductance or resistance). The first part of the electrical property sensor may measure the electrical property at a first location along the stem 10, and the second part of the electrical property sensor may measure the electrical property at a second location along the stem.

The first and second locations along the stem may be adjacent to one another or may be spaced apart from one another.

Measurement of differential capacitance as opposed to absolute capacitance is beneficial in that it may help to reduce background noise, and to reduce the effect of background capacitance. The rate of change of absolute or differential capacitance with respect to time may be measured. Any other parameter may be measured, such as for example distance along the stem.

In an embodiment, as the stem is pushed through the electrical property sensor 34 by the grabber 32, the differential capacitance and/or the rate of change of the differential capacitance of successive portions of the stem may be measured. As previously mentioned, the nodes 12 of the stem 10 have a greater fibre content than the internodal portions 14. In addition, the internodal portions 14 have a greater water content than the nodes 12. Since water has a relatively high permittivity, the nodes 12 have a lesser permittivity than the internodal portions 14. The greater the permittivity of the material between the electrodes, the greater the capacitance measured between those electrodes. Consequently, when a node 12 is between a pair of electrodes 50, 52 or 52, 54 the capacitance measured between those electrodes is less than when an internodal portion 14 is between those electrodes. Consequently, processing can be applied to the signal output from the electrodes so as to detect when a node 12 passes between an electrode pair.

In another embodiment of a capacitance sensor, shown in figure 6, the sensor comprises three arcuate electrodes 58, 60, 62. The arcuate electrodes are disposed upon a tube 56. Each arcuate electrode subtends an angle of approximately 120º. The electrodes may be made of any appropriate conducting material, for example copper tape, which may for example be 12.7mm wide. Two of the electrodes 58, 62 are adjacent one another, angularly aligned with respect to the longitudinal axis of the tube 56, and separated by an appropriate distance, for example 2mm. The third electrode 60 is rotated around the longitudinal axis of the tube 56 relative to the other electrodes 58, 62 by approximately 180º. The third electrode 60 is positioned along the tube 56 so that it is approximately central with respect to the other two electrodes 58, 62. Electrodes 58, 60 and 60, 62 form two pairs of electrodes in a similar manner to electrodes 50, 52 and 52, 54 of the previously described embodiment.

In order to measure capacitance (for example in the embodiments of the invention shown in figures 5 and 6), an electric field between each of the electrode pairs is created. Capacitance is a measure of how the electric field between each of the electrode pairs is affected by whatever material the created electric fields pass through. The configuration of the electrodes used determines the geometry of the field which is created. For example, it is thought that the two electrode embodiments of figures 5 and 6 may set up electric fields which look like those shown in figures 7 and 8 respectively. The figures show that the electric field produced by the ring electrodes penetrates less deeply into the cane stem 10 than that of the arcuate electrodes.

The capacitance of all material through which the electric field passes is measured. This includes not only the stem 10, but also the plastic tube 56 and the air between the plastic tube 56 and the stem 10. Since the permittivity of air is compared to that of a water-rich stem, its presence can be ignored, although it may contribute to measured noise. The plastic tube is fixed with respect to the electrodes and can also be ignored.

Due to the fact that the electric field of the ring electrodes is thought to penetrate less deeply into the stem 10 than the arcuate electrodes, it is thought that the ring electrodes may be more sensitive to surface effects (i.e. variations in the properties of the surface of the stem), whereas the arcuate electrodes may be more sensitive to changes in the properties of the entire thickness of the cane stem 10. For this reason, the ring electrodes are thought to be more sensitive to changes in the thickness of the stem 10 or to lateral movement of the stem 10 as it passes through the tube 56. The detection of such changes may make it more difficult to distinguish between nodes and internodal portions.

It may be preferable to use an electrode configuration which creates an electric field that penetrates all the way through the stem 10 (for example that shown in figure 8). When such a configuration is used, the electric field interacts with a greater volume of the stem. This means that any variation in the permittivity of the stem will affect a larger portion of the generated electric field and hence the capacitance change which is measured will be much greater. This in turn allows any change in permittivity and hence capacitance resulting from the presence of a node to be more readily detected.

As previously mentioned, when moving the stem 10 through the electrical property sensor 34, it is possible that the thickness of the stem 10 and hence the volume of stem 10 between the electrodes may vary. For example, if the thickness of the stem 10 decreases, the volume of stem between the electrodes will decrease, which in turn will lead to an decrease in capacitance measured between an electrode pair (when compared to a similar part of a stem that is of a greater thickness). This means that an decrease in capacitance would be measured for not only the presence of a node 12, but also if there is an decrease in thickness of an internodal portion 14. This could lead to the electrical property sensor 34 incorrectly identifying a thinner internodal portion 14 as a node 12. Measuring the differential capacitance between the two sets of adjacent electrodes 50, 52 and 52, 54 (or 58, 60 and 60, 62) helps to reduce the possibility of such an incorrect identification occurring. This is because, should the thickness of the stem 10 change, it is likely to do so over a considerable length. As such, it is likely that the thickness of the stem 10 between electrodes 50 and 52, for example, is very similar to the thickness of the stem 10 between electrodes 52 and 54. Since the differential capacitance is calculated by comparing (e.g. subtracting) the measured capacitance between one set of electrodes with the measured capacitance between the other set of electrodes, any element of measured capacitance which is common to both sets of electrodes will be eliminated. In this way, by measuring differential capacitance as opposed to absolute capacitance, the effect of varying stem 10 thickness on the measured capacitance is reduced. In addition, the effects of other factors which make node detection more difficult are also reduced. Such factors may include background noise, including background capacitance such as the capacitance due to the air in the tube.

When measuring the differential capacitance in some embodiments of the invention, it may be beneficial for the first and second capacitance measurements to be taken simultaneously. However it is not necessary that the first and second measurements be taken simultaneously. Taking simultaneous measurements has the benefit that any background or noise measured in each measurement will be measured at the same time, and may be minimised or even completely eliminated by subtracting one measurement from the other. If the measurements are taken at different times, then the background or noise may have changed between measurements, and the subtraction may be less effective in reducing background or noise. If the measurements are taken in quick succession (compared with the speed at which the background or noise changes), then the subtraction may be effective in reducing background or noise.

Reducing the background or noise may allow a signal analyser and/or electrical property sensor to be used which has a narrower dynamic range than would be the case if the background or noise was not reduced. A signal analyser and/or electrical property sensor with a narrower dynamic range may be cheaper than a signal analyser and/or electrical property sensor with a wider dynamic range.

In an embodiment of the invention, each of the electrodes is attached to an integrated circuit (IC) which measures the capacitance. One example of a suitable IC is an off-the-shelf capacitance-to-digital converter such as an AD7745 or AD7746 supplied by Analog Devices Inc. of Norwood, MA, USA. These ICs measure the capacitance between each electrode pair using a Σ-Δ or charge balancing method, with an oscillating signal at 32kHz being supplied to at least one of the electrodes. For example, if the differential capacitance is to be measured using the embodiments shown in figures 5 and 6, a common oscillating excitation signal is provided from the AD7745 to the central electrode, 52 and 60 respectively (via pin EXCA of the AD7745 as shown on the data sheet for that IC). The capacitance between the central electrode 52, 60 and each of the outer electrodes, 50, 54 and 58, 62 respectively, is then measured via a connection between each of the outer electrodes, 50, 54 and 58, 62, and a capacitive input of the AD7745 (i.e. pins CIN1(+) and CIN1(-) as shown on the data sheet). The differential capacitance is then measured by the AD7745, whereby the capacitance measured between the EXCA and CIN1(-) pins is subtracted from the capacitance measured between the EXCA and CIN1(+) pins. Further information concerning the operation of the ICs is readily available from data sheets available from the manufacturer.

It will be appreciated that any appropriate frequency of oscillating excitation signal may be used. For example, the frequency of the oscillating excitation signal may be between 1Hz and 100MHz.

Other embodiments of invention may take an absolute measurement of the capacitance rather than a differential one. An example of a way in which this could be done is to provide oscillating excitation signal to a first electrode (for example from the EXCA pin of an AD7745) and to measure the capacitance between the first electrode and a second electrode (for example via the CIN1(+) pin of an AD7745). The first and second electrodes may be any suitably positioned electrodes which will result in an electric field which penetrates the cane stem 10, as discussed above. Examples of possible first and second electrode pairs include 50, 52; 52, 54; 58, 60 and 60, 62. It is only necessary to use a single electrode pair to measure an absolute capacitance. Additional processing of the measurements may be used to remove or reduce background noise, including background capacitance. This may include comparing measurements made at different times.

As an alternative to measuring capacitance (both absolute and differential) using an oscillating signal (such as the excitation signal above), the capacitance and hence any subsequently calculated differential capacitance may be measured using a non-oscillating signal. For example, the charge and/or discharge time of a capacitor formed between an electrode pair may be measured.

Figures 9 to 12 show results which were obtained using an AD7746, the output of which was attached to a National Instruments USB-8451 I²C/SPI to USB interface. The results were recorded using National Instruments LabView. All of the figures show graphs of capacitance against time. The approximate time at which a node 12 passes through the electrical property sensor is indicated by the line N. The results shown in both figures 9 and 10 were taken using the electrode shown in figure 5.

Figure 9 shows the absolute capacitance measured using one of the electrode pairs, whereas figure 10 shows the differential capacitance which was obtained using both electrode pairs. The stem 10 was passed through the electrical property sensor 34 in each case at a speed of approximately 0.5m/s.

It can be seen from figure 9 that the internodal portions 14 of the stem 10 either side of the node have different capacitances. The node 12 is generally represented as a step function (with a small peak), which links two plateau regions of the graph that correspond to the capacitance of the internodal portions 14.

Figure 10 shows a clear dip in the differential capacitance at around the time N that the node passed through the electrical property sensor.

Figures 11 and 12 were taken using the arcuate electrodes shown in figure 6. Figure 11 shows the absolute capacitance measured using one of the electrode pairs, whereas figure 12 shows the differential capacitance which was obtained using both electrode pairs.

In figure 11 it can be seen that the capacitances of the internodal portions 14 are very similar. There is a large peak in capacitance as the node 12 passes through the electrical property sensor.

The differential capacitance response shown in figure 12 is very similar to that of figure 10. The differential capacitance of the internodal portions 14 either side of the node 12 is very similar, but a dip is present when the node 12 passes through the electrical property sensor.

It may be noted that Figure 11 indicates that the absolute capacitance of the node 12 is greater than that of the internodal portions 14. This is contrary to what was predicted and described above. It is believed that the reason for this discrepancy is that the results were taken using a sugar cane stem which was significantly desiccated. As such, the internodal portions which are usually water-rich had partially dried. Since it is the presence of the water, with its high permittivity, which results in the internodal portions 14 having a relatively high capacitance, this effect was not seen.

The output of the capacitance sensing IC (or other appropriate electrical property sensor) is supplied to a signal analyser 72 where the data is analysed to determine the positions of nodes 12 along the stem 10. The data may be processed prior to being analysed. Processing of the data may include analogue conditioning, such as filtering. For example, a band pass filter may be used to remove any noise which has a frequency which is significantly above or below that of the desired signal. The frequency of the desired signal can be approximately determined from the rate at which nodes pass through the electrical property sensor. This is a function of the spacing of the nodes and the speed at which the stem 10 is fed through the electrical property sensor. Another type of processing which may be applied to the signal is digital signal processing, such as Fourier transforms and the like. Again, in this way, unwanted frequency elements of the signal can be removed or minimised. This may be done by Fourier transforming the signal into the frequency domain, removing unwanted frequencies and then inverse Fourier transforming the signal from the frequency domain back into its original domain. Noise elements of the signal may result from, for example, mains ‘hum’, the resonant frequency of the cutting machine and the average frequency at which cuts are made.

The signal analyser 72 may use any appropriate analysis of the output of the electronic property sensor to determine the presence or otherwise of a node 12. For example, the signal analyser 72 may compare the output of the electronic property sensor to a threshold. If the output is greater than the threshold then this may be indicative of the presence of a node. If the output of the electrical property sensor is less than the threshold, then this may be indicative of the absence of a node. In other embodiments, an output of the electrical property sensor which is less than the threshold may indicate the presence of a node and an output of the electrical property sensor which is greater than the threshold may indicate the absence of a node.

In another embodiment, the output of the sensor may form part of a set of sensor outputs. The set may for example comprise absolute measurements or differential measurements. The signal analyser may generate the set of sensor outputs by storing the output of the sensor over a period of time.

In some embodiments, the electrical property sensor may be capable of measuring an electrical property of the stem simultaneously at multiple locations along the stem. The resulting multiple measurements may be stored by the signal analyser, and may form part of a set of sensor outputs.

The signal analyser may compare a stored output of the electrical property sensor to an output of the electrical property sensor which is measured at a later time. In the case where the electrical property sensor takes multiple simultaneous measurements, the signal analyser may compare a measurement taken at one location with measurements taken at other locations. The signal analyser may compare two measurements of the same location along the stem, the measurements having been taken at different times using sensors located at different positions. The signal analyser may compare two measurements of different locations along the stem, the measurements having been taken at different times using sensors located at different positions. The different locations along the stem may be adjacent to one another or may be separated from one another.

A set of sensor outputs may be analysed using any suitable analysis technique. For example, a set of sensor outputs may be analysed using cross-correlation. For example, a set of sensor outputs recorded when a node is present may be cross-correlated with a set of subsequently received sensor outputs. If the cross-correlation indicates that the subsequently received set of sensor outputs resembles the recorded set of outputs, then it is likely that a node has been detected. The recorded set of sensor outputs may comprise an average generated from measurement of a plurality of nodes.

In the embodiments of the invention described above which relate to differential capacitance, the differential capacitance is measured by measuring two separate capacitances and then subtracting one from the other. The subtraction is performed by the IC (i.e. before the signal analyser 72) and the result is then analysed by the signal analyser. However, it will be appreciated that the two separate measured capacitance values may be subtracted by the signal analyser.

In some embodiments, the rate of change of the measured electrical property of the stem with respect to time may be measured. Alternatively, the rate of change of the measured electrical property may be measured with respect to any other appropriate parameter, such as position along the stem. In such embodiments, the signal analyser 72 may analyse the rate of change measurements so as to identify measurements which have a value which is similar to that expected due to the speed at which the stem is moved through the electrical property sensor. For example, if it is known (or determined empirically) that the average difference in capacitance between a node and internodal portion is 2 femtoFarads, and that the speed at which the stem is travelling results in the change in capacitance between a node and internodal portion occurring over a period of 0.01 seconds, then the signal analyser may identify rate of change measurements with a value of about 200 femtoFarads per second. Measurements identified in this way may then be interpreted by the signal analyser as being indicative of the presence of a node.

In embodiments of the invention which measure the rate of change of the measured electrical property of the stem, it may be beneficial to remove high frequency noise components of the signal. This high frequency noise may give rise to an erroneous measurement of the rate of change of the measured electrical property. Removal of high frequency noise components of the signal may be carried out using analogue filtering or digital signal processing techniques as described above. Such analogue filtering or digital signal processing may be carried out by the signal analyser.

The signal analyser 72 may generate any appropriate output signal so as to indicate to the cutting machine control system 47 that a node has been detected. An example of such a signal which may be generated by the signal analyser 72 is a pulse of elevated or decreased voltage.

The cutting machine control system 47 synchronises the sensing of the nodes 12 and the cutting of the stem segments 16 such that the machine 20 cuts segments 16 containing one detected node 12. In order to provide this synchronisation, the cutting machine control system 47 takes various parameters into account. Examples of these parameters and how they may be used to synchronise node 12 detection and stem 10 cutting are described below.

In an embodiment, the following information is provided to the cutting machine control system: the distance between the mid-point between the blades 42, 44 and the portion of the electrical property sensor which detects a node 12; the speed at which the grabber 32 and hence the stem 10 is moving through the conduit; the time at which a node 12 is sensed; and the time the electrical property sensor takes to process the measurements and determine the presence of a node 12 (also known as the sensor processing lag time). Ignoring the sensor processing lag, the time, t_b, at which the blades 42, 44 must be actuated to cut a segment 16 which contains the detected node 12 may be determined as:

$$t_b = t_d + \frac{d}{v} \qquad (1)$$

where t_d is the time at which the node is sensed, d is the distance between the mid-point between the blades 42, 44 and the portion of the electrical property sensor which detects a node 12, and v is the speed of the grabber 32. However, incorporating the sensor processing lag time, t_l, the relationship may be determined as:

$$t_b = t_d - t_l + \frac{d}{v} \qquad (2)$$

In another embodiment, the cutting machine control system may be provided with information including: the distance between the mid-point between the blades 42, 44 and the portion of the electrical property sensor which detects a node 12; the position of the grabber 32 when a node 12 is sensed; and the distance travelled by the grabber 32 during the sensor processing lag time. In this case, ignoring sensor processing lag, the position of the grabber, x_b, at which the blades 42, 44 must be actuated to cut a segment 16 which contains the detected node 12 may be determined as:

$$x_b = x_d + d \qquad (3)$$

where x_d is the position of the grabber 32 when a node 12 is detected and d is the distance between the mid-point between the blades 42, 44 and the portion of the electrical property sensor which detects a node 12. Again, this relationship can be modified to account for sensor processing lag. In this case, the relationship may be determined as:

$$x_b = x_d - d_l + d \qquad (4)$$

where d_l is the distance travelled by the grabber 32 during the sensor processing lag time.

As mentioned further above, electrical properties other than capacitance may be measured by the electrical property sensor. A electrical property sensor 34 suitable for measuring resistance is shown in figure 13, and comprises two electrodes 46, 48, each of which comprises a conductive cylinder which is biased towards the other electrode. This biasing may be provided for example by springs (not shown), and helps to ensure that good contact is maintained between both electrodes 46, 48 and the stem 10. The resistance of the stem location which is between the electrodes 46, 48 is measured via the electrodes 46, 48.

An electrical property sensor suitable for measuring inductance is shown in figure 14. The sensor 34 comprises two coils 64, 66 which are disposed upon the ends of a generally c-shaped ferromagnetic core 68. A non-ferromagnetic tube 70 runs between the core ends and acts as a conduit for the stem 10. In use, an oscillating signal is supplied to one of the coils 64. The signal results in a magnetic field being generated by the coil 64. The magnetic field propagates through both the core 68 and the space between the core ends to the other coil 66. The magnetic field which reaches the coil 66 is partially dependant on the permeability of the material between the core ends. Including the permeability of the cane stem 10. The magnetic field at the coil 66 causes a current to be induced in the coil 66 which can be measured. Any difference in the permeability of nodes 12 compared to that of the internodal portions 14 will result in the measured inductance of the nodes 12 and internodal portions 14 being different. Variations in the inductance will be measurable as a result of whether the location along the stem 10 being measured is a node 12 or an internodal portion 14. In this way, the nodes 12 can be detected. The frequency of the oscillating signal may be between 1 MHz and 50MHz and may be between 5MHz and 15MHz.

In a similar manner to that of the capacitance sensor described above, two inductance sensors (or resistance sensors) may be positioned adjacent one another such that they can measure the inductance (or resistance) of adjacent portions of the stem 10 simultaneously. In this way a measure of differential inductance can be taken which will be much less susceptible to any background inductance or noise.

Although specific examples of electrical property sensor configuration have been described, it is within the scope of the invention to use any configuration of electrical property sensor which can measure a component of the impedance of the stem 10 such that that measurement may be used to distinguish between nodes 12 and internodal portions 14.

The sensor apparatus may comprise electrical property sensors configured to measure more than one electrical property. For example, the sensor apparatus may comprise an electrical property sensor configured to measure capacitance and an electrical property sensor configured to measure inductance. Any combination of electrical property sensors may be provided.

The sensor apparatus may comprise more than one type of sensor. For example, it may comprise an electrical property sensor (e.g. resistance, capacitance or inductance sensor) and a different type of electrical property sensor, or any other appropriate type of sensor (pressure, optical etc). The signals from all the sensors may then be supplied to the signal analyser such that it may determine the presence of a node or otherwise.

Although the above described embodiments generally refer to one electrode/coil pair to determine absolute capacitance/inductance; or two electrode/coil pairs to determine differential capacitance/inductance; it is within the scope of the invention to provide any number of electrodes/coils. In such embodiments, the measurements from the electrodes/coils may provide more detailed information about the structure of the stem.

More than two stem locations may have their respective electrical properties measured simultaneously. For example, if an array of electrodes were to be positioned along the length of the conduit, it may be possible to determine the location of the nodes whilst the cane stem is stationary. Alternatively, data from different electrodes may be combined and processed to enable tomography of the stem.

In an embodiment of the invention described above, differential capacitance is measured by taking a first capacitance measurement between the centre electrode and a first outer electrode and by taking a second capacitance measurement between the centre electrode and a second outer electrode. These measurements are then compared (e.g. one measurement is subtracted from the other, although any appropriate comparison may be made) to produce a resultant output which is the differential capacitance. It is within the scope of the invention that, in certain embodiments, a differential measurement may be made of any appropriate component of impedance. In order to achieve this, two measurements are taken of the appropriate component of the impedance of the stem. The first measurement is made at a first location along the stem and a second measurement is made at a second location along the stem. The first and second measurements of the component of the impedance may then be compared (for example, by subtracting one from the other) to produce a resultant output which is a differential measurement of the appropriate component of the impedance.

Previously described embodiments relating to obtaining a differential measurement of an electrical property may utilise two parts of the electrical property sensor to take two separate measurements of the electrical property which are then compared. In other embodiments, a single part of an electrical property sensor may be used to take two successive measurements of an electrical property of the stem at two different locations along the stem. These two measurements may then be compared to produce a differential measurement of the electrical property.

Although the embodiments of the capacitance sensor described have curved electrodes which are supported by a cylindrical support structure, the electrodes may be of any shape and may be supported by any support structure which will allow a cane stem to pass through it. One such example is a longitudinal box support structure which has planar electrodes fixed to opposing sides of the box. This embodiment has the benefit that the electric field created between the electrodes is substantially uniform. The uniform nature of the electric field results in all the parts of the stem though which the field passes having an equal interaction (per unit volume) with the electric field. For example, a given volume of the stem at the centre of the stem will have an equal opportunity to interact with the electric field as the same volume of the stem at the surface. As previously discussed, the effect of the interactions on the measured capacitance will be determined by the electrical properties of the volume of stem concerned. However, since all parts of the stem will have an equal opportunity to interact with the electric field, this may help to minimise inaccurate measurements caused by surface noise.

The planar electrodes may be provided using any suitable support structure.

As previously discussed, in some embodiments of the invention, particularly those which are sensitive to surface effects (for example the capacitance sensor of figures 5 and 7), lateral movement of the cane stem 10 may have a substantial effect on the sensor output. This may result in either an inability of the sensor to detect nodes or erroneous detections. Lateral movement of the stem may result from vibrations of the machine, for example from the operation of the cutting mechanism, or from the stem having a crooked shape along its length. In order to suppress any lateral movement of the cane stem 10, the cutting machine may incorporate a lateral movement damper. The damper may be located between the electrical property sensor and the cutting means or at any other appropriate location.

One example of a lateral movement damper is at least one pair of biased opposing rollers, arranged such that the cane stem 10 passes between them. The rollers are biased towards each other by biasing means, such as a spring. The rollers may contact the stem and apply a force to the stem from the biasing means. The force applied to the cane stem may, for example, centralise the stem 10 within the electrical property sensor. However, the biasing force may also locate the stem 10 at any other appropriate position within the electrical property sensor.

The rollers may have a concave profile. This will aid centralising the stem in a direction parallel to the length of the rollers. This is because the profile of the rollers is such that, should the stem be in a non-centralised position along the rollers, each roller will apply force to the stem which includes a component that urges the stem towards a centralised position along the rollers.

Although the electrical property sensor is described as being between the conduit 28 and cutting mechanism 36, it is feasible to locate the electrical property sensor anywhere upstream of the cutting mechanism 36. For example, the electrical property sensor may be located somewhere else on the cutting machine 20, e.g. in the conduit 28. Alternatively, the electrical property sensor may be located remote to the cutting machine. It may be possible for the electrical property sensor to detect the nodes before they reach the cutting machine and then have information concerning the locations of the nodes on each stem conveyed to the machine either by some form of electronic signal or by some form of tag attached to, or made on, each stem.

A sensor apparatus according to the present invention differs from some known sensors in that it may be considered to not have a transmitter configured to transmit electromagnetic waves. Equally, the sensor apparatus may be considered not to have a received configured to receive electromagnetic waves.

The cutting machine described above and the cutting mechanism described above are examples of cutting machines and cutting mechanisms. Other cutting machines and cutting mechanisms may be used.

Although the embodiments of the invention described above relate to determining the presence of a node or otherwise within a stem of sugar cane, the invention may be utilised to detect the presence of a node or otherwise within any plant, the stem of which comprises nodes and internodal portions, the nodes and internodal portions having different electrical properties. Further examples of such plants include other members of the Gramineae or Poaceae family, for example bamboo and elephant grass.

Although the above embodiments are primarily concerned with the detection of nodes within the stem, it will be appreciated that other characteristics of the stem may be detected using a sensor apparatus according to the present invention. For example a portion of the stem which has an undesirable characteristic (for example rot, disease or desiccation) may be detected due to variations in the measured electrical property between a healthy or otherwise portion of the stem. For example, due to the fact that a desiccated portion of the stem will have a lesser water content than that of a healthy portion, the measured capacitance of a desiccated portion of the stem will be less than that of a healthy portion (due to the relatively high permittivity of water as mentioned above). Once a portion of the stem which has an undesirable characteristic has been identified by the sensor apparatus it may be cut from the remainder of the stem by the cutting machine and sorted or discarded.

It is to be appreciated that modifications to the above-described embodiments may be made without departing from the scope of the invention as defined in the appended claims.

CLAIMS:

1. A method of detecting the presence of a node within a stem of a plant, the method comprising:

making two measurements of a component of the electrical impedance of the stem, wherein a first measurement is made at a first location along the stem and a second measurement is made at a second location along the stem;

comparing the first measured component of the electrical impedance and the second measured component of the electrical impedance to produce a resultant output; and

analysing the resultant output in order to determine the presence of a node or otherwise at the first location or the second location.

2. A method according to claim 1, wherein the component of the electrical impedance is capacitance, inductance or resistance.

3. A method according to claim 1 or claim 2, wherein the first and second measurements are simultaneous.

4. A method according to any of the preceding claims, wherein comparing the first measured component and the second measured component comprises determining the difference between the first measured component and the second measured component.

5. A method according to any of the preceding claims, wherein the first measurement is part of a set of first measurements, each member of the set of first measurements being measured at a different time; and

the second measurement is part of a set of second measurements, each member of the set of second measurements being measured at a different time; and

wherein the resultant output is part of a set of resultant outputs, the set of resultant outputs being analysed in order to determine the presence of a node or otherwise.

6. A method according to any of claims 1 to 4, wherein the first measurement is part of a set of first measurements, each member of the set of first measurements being measured at a different location along the stem; and

the second measurement is part of a set of second measurements, each member of the set of second measurements being measured at a different location along the stem; and wherein the resultant output is part of a set of resultant outputs, the set of resultant outputs being analysed in order to determine the presence of a node or otherwise.

7. A method according to any of the preceding claims, wherein the first location is adjacent the second location.

8. A method according to any of the preceding claims, wherein the component of electrical impedance is capacitance or inductance, measured using an electrical property sensor which does not contact the stem.

9. A method according to any of claims 1 to 8, wherein the component of impedance is measured by an electrical property sensor, the electrical property sensor having a first part and a second part and wherein the first measurement is made by the first part and the second measurement is made by the second part.

10. A method of detecting the presence of a node within a stem of a plant, the method comprising:

measuring the inductance or resistance of a location along the stem; and

analysing the measured inductance or resistance so as to determine the presence of a node or otherwise at that location.

11. A method according to claim 10, wherein the inductance of the stem is measured using an electrical property sensor which does not contact the stem.

12. A method according to any of the previous claims, wherein the plant is a plant from the Gramineae or Poaceae family.

13. A method according to any of the preceding claims, wherein the method further comprises generating a signal to indicate the presence of a node.

14. A plant stem cutting method comprising the method of claim 13, wherein the generated signal is supplied to a control system of a cutting machine, the control system actuates a cutting mechanism of the cutting machine in response to the signal; and the cutting mechanism cuts a portion of the stem which contains the node from the remainder of the stem.

15. A sensor apparatus suitable for measuring a component of the electrical impedance of a stem of a plant, the sensor apparatus comprising an electrical property sensor and a signal analyser;

wherein the electrical property sensor is configured to make two measurements of the component of the electrical impedance of stem, a first measurement being made at a first location along the stem and a second measurement being made at a second location along the stem; and

wherein the signal analyser is configured to compare the first and second measurements to produce a resultant output, and to analyse the resultant output in order to determine the presence of a node or otherwise at the first location or the second location.

16. A sensor apparatus according to claim 15, wherein the component of the electrical impedance is capacitance, inductance or resistance.

17. A sensor apparatus according to either claim 15 or claim 16, wherein the signal analyser is configured to determine the difference between the first measurement and the second measurement.

18. A sensor apparatus according to any of claims 15 to 17, wherein the first measurement is part of a set of first measurements, each member of the set of first measurements being measured at a different time;

the second measurement is part of a set of second measurements, each member of the set of second measurements being measured at a different time; and

wherein the resultant output is part of a set of resultant outputs, the signal analyser being configured to analyse the resultant output set in order to determine the presence of a node or otherwise.

19. A sensor apparatus according to any of claims 15 to 17, wherein the first measurement is part of a set of first measurements, each member of the set of first measurements being measured at a different location along the stem;

the second measurement is part of a set of second measurements, each member of the set of second measurements being measured at a different location along the stem; and

wherein the resultant output is part of a set of resultant outputs, the signal analyser being configured to analyse the resultant output set in order to determine the presence of a node or otherwise.

20. A sensor apparatus according to any of claims 15 to 19, wherein the first location is adjacent the second location.

21. A sensor apparatus according to any of claims 15 to 20, wherein the component of the electrical impedance is resistance, and the electrical property sensor comprises at least two electrodes which are configured to contact the stem.

22. A sensor apparatus according to any of claims 15 to 20, wherein the component of electrical impedance is capacitance and the electrical property sensor comprises at least two electrodes.

23. A sensor apparatus according to claim 22, comprising a common electrode, a second electrode and a third electrode, the electrical property sensor being configured make the first measurement between the common electrode and the second electrode; and make the second measurement between the common electrode and the third electrode.

24. A sensor apparatus according to any of claims 15 to 20 wherein the component of electrical impedance is inductance, and the electrical property sensor comprises at least two coils.

25. A sensor apparatus according to claim 24 wherein the coils are disposed upon a member made from magnetic material which forms a discontinuous loop, the discontinuous loop being configured to receive the stem within or adjacent to the discontinuity of the discontinuous loop.

26. A sensor apparatus according to any of claims 15 to 25, wherein the electrical property sensor comprises a first part configured to make the first measurement, and a second part configured to make the second measurement.

27. A sensor apparatus suitable for measuring the resistance or inductance of a stem of a plant, the sensor apparatus comprising an electrical property sensor and a signal analyser, the electrical property sensor being configured to measure the resistance or inductance of a location along the stem, wherein the signal analyser is configured to analyse an output of the electrical property sensor indicative of the measured resistance or inductance and determine if a node is present at that location.

28. A sensor apparatus according to any of claims 15 to 27, wherein the plant is a plant from the Gramineae or Poaceae family.

29. A plant stem cutting machine comprising a sensor apparatus according to any of claims 15 to 28, wherein the signal analyser is additionally configured to generate a signal indicative of the presence of a node, the plant stem cutting machine additionally comprising a control system and a cutting mechanism, wherein the generated signal is supplied to the control system, and wherein the control system is configured to actuate the cutting mechanism in response to the signal such that the cutting mechanism cuts a portion of the stem which contains the node from the remainder of the stem.

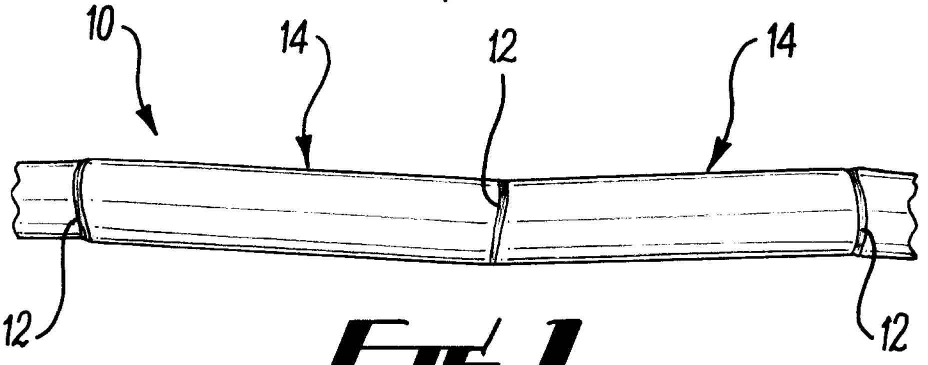


FIG. 1

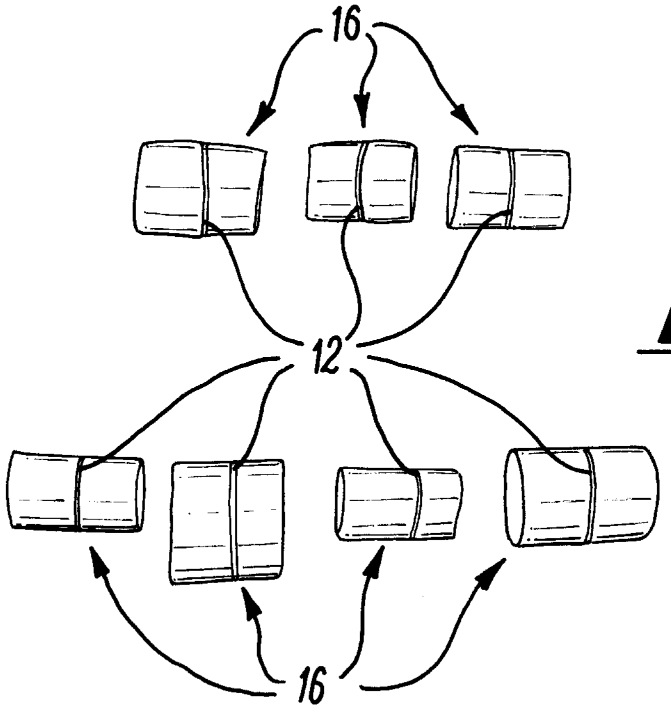


FIG. 2

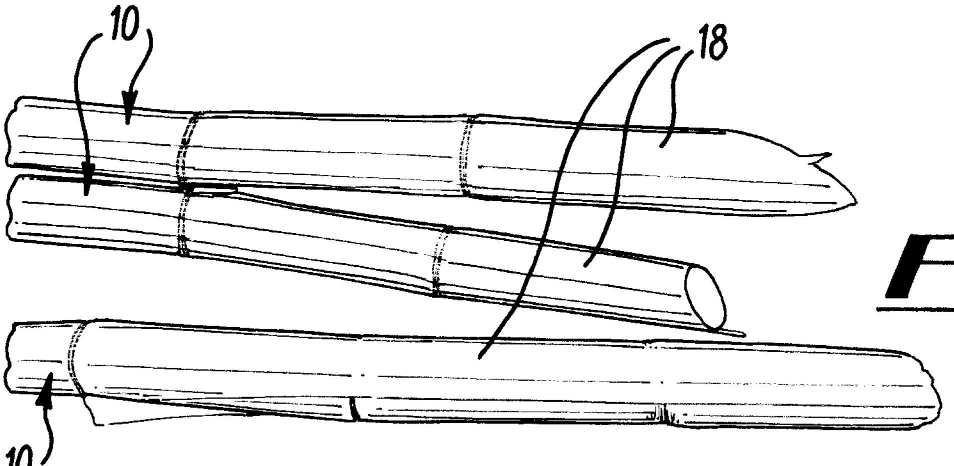


FIG. 3

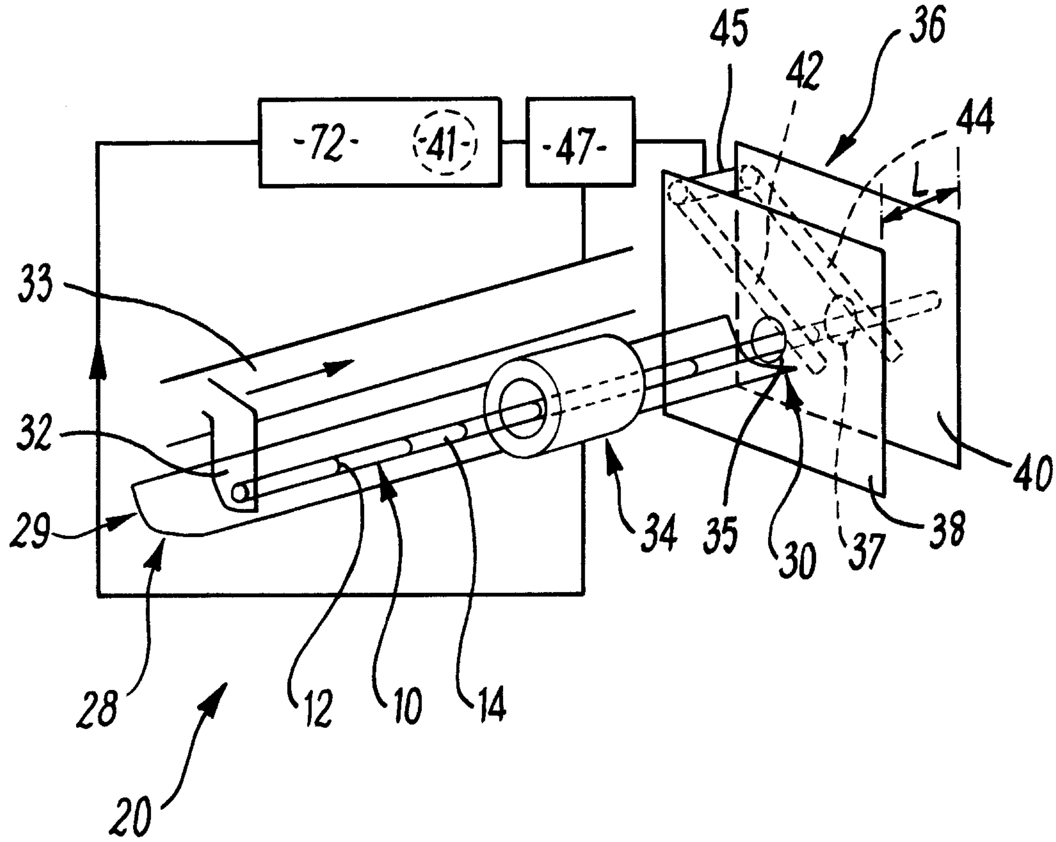


FIG. 4

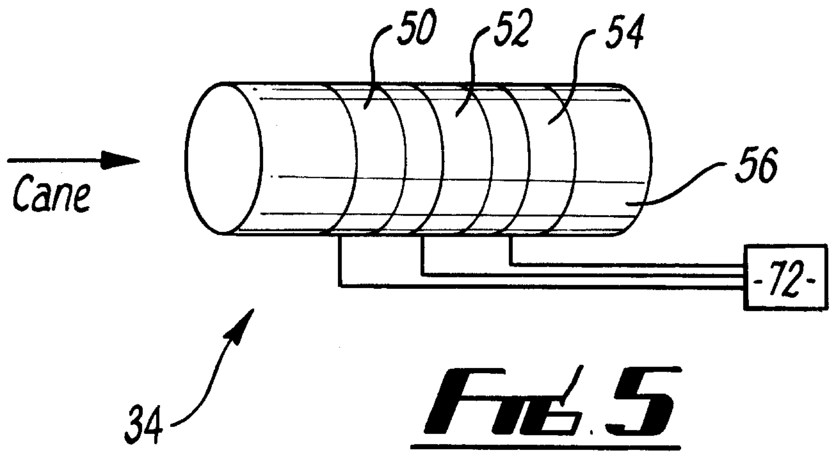


FIG. 5

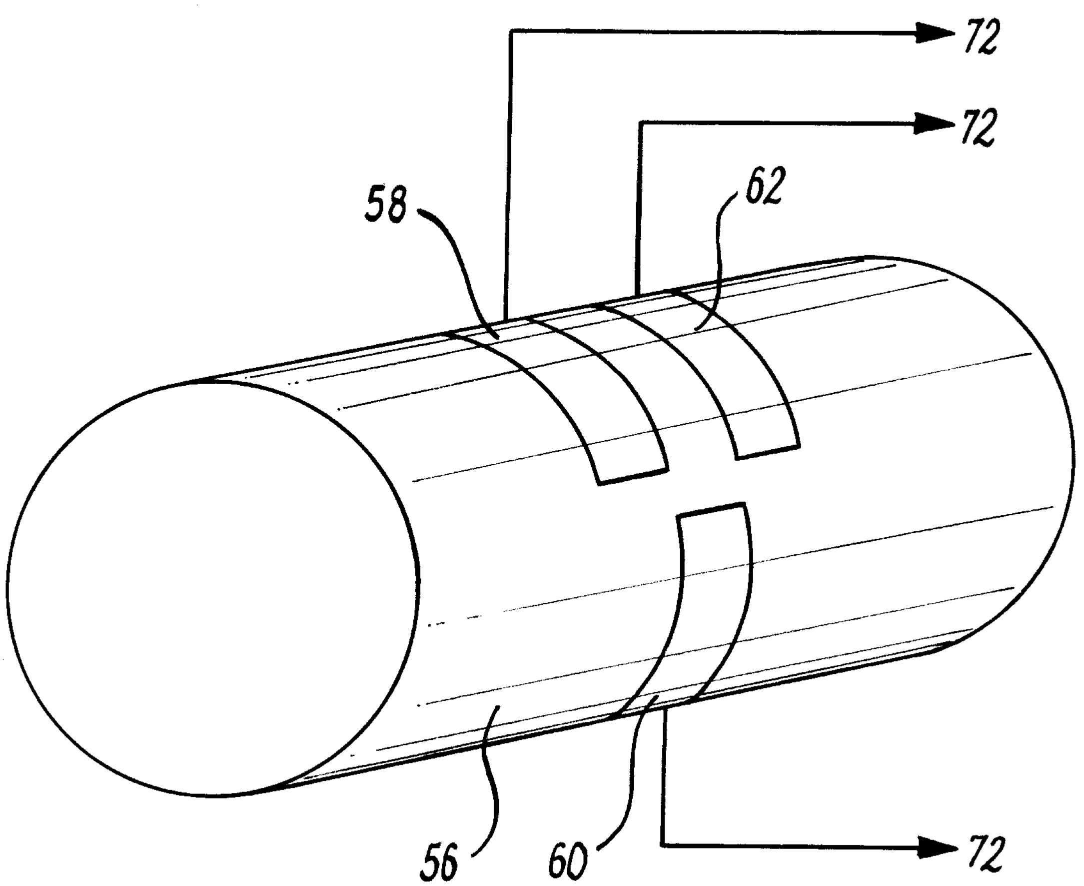


FIG. 6

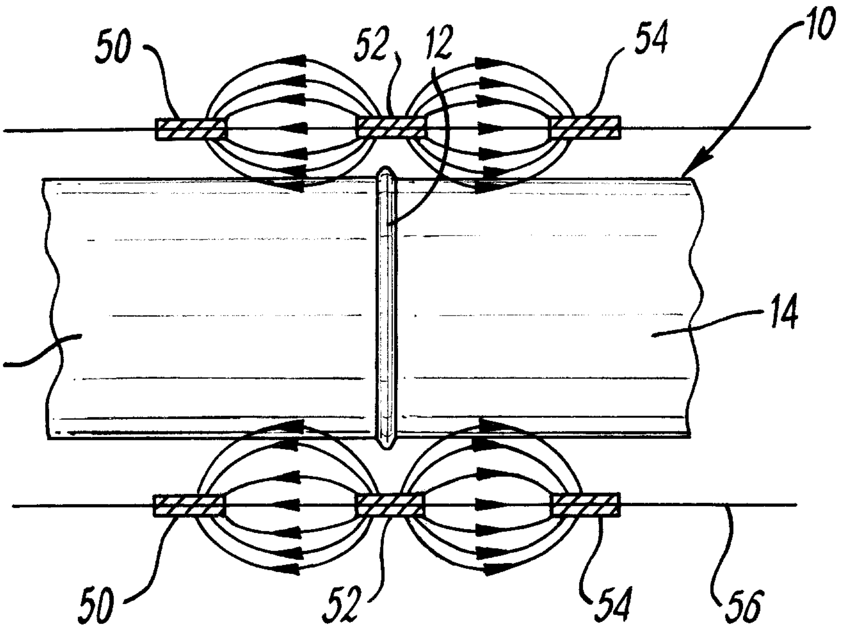


FIG. 7

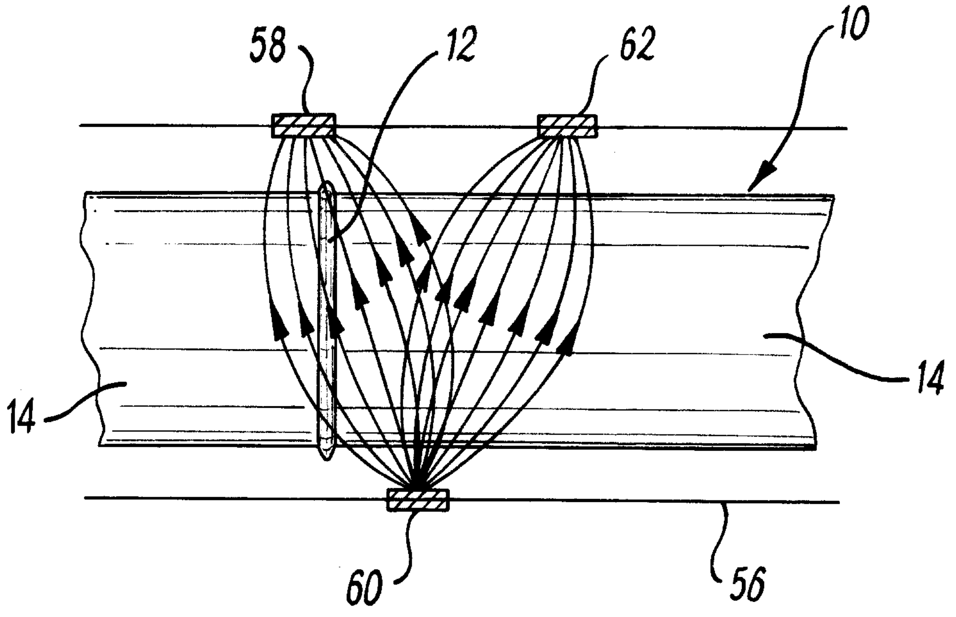
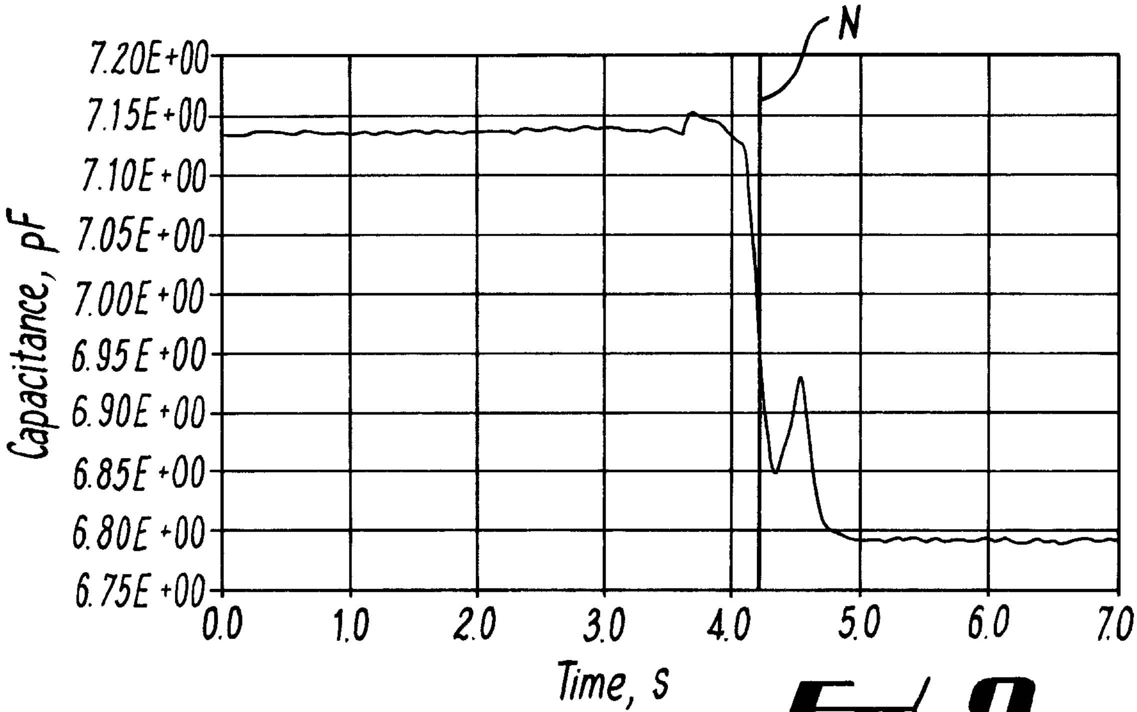


FIG. 8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7.00E+00
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6.85E+00
6.80E+00
6.75E+00
Capacitance, pF
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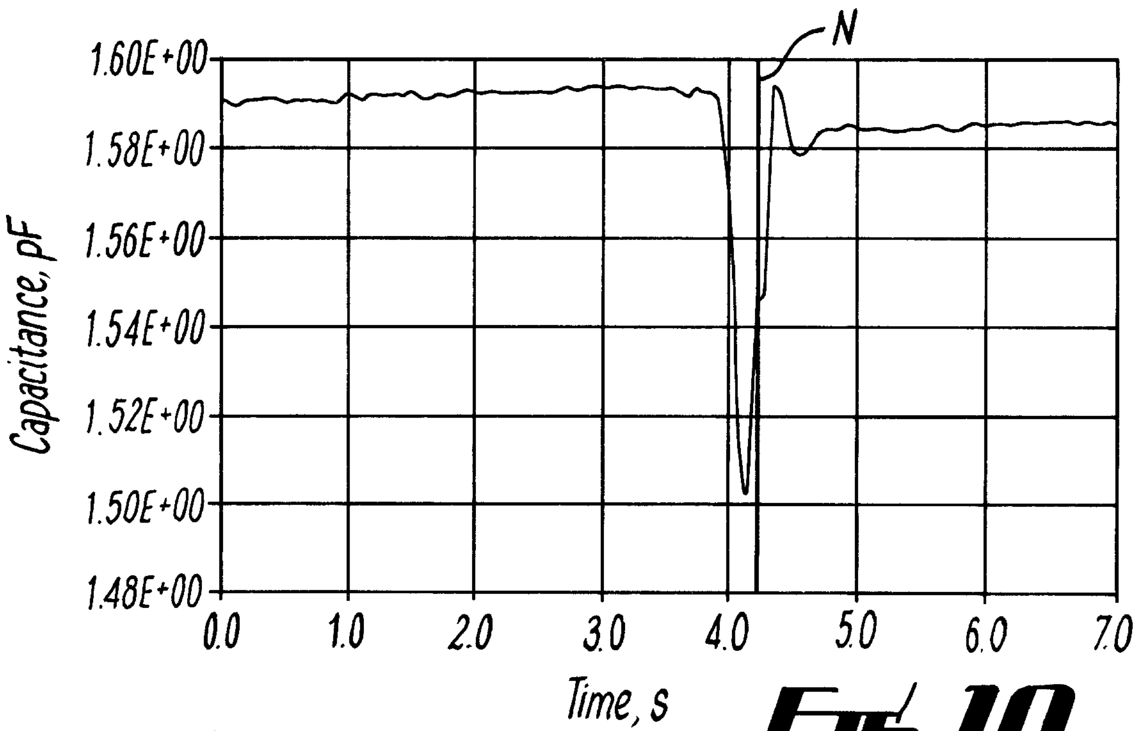
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Time, s

FIG. 9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Capacitance, pF
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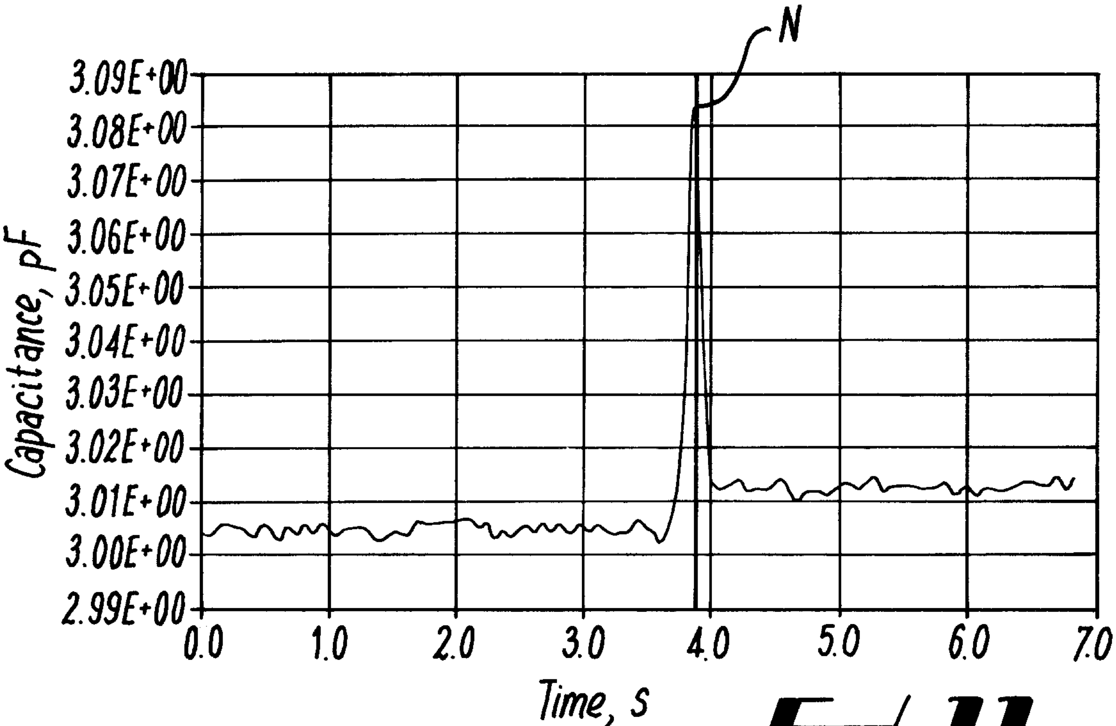
3.0
4.0
5.0
6.0
7.0
Time, s

FIG. 10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3.05E+00
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3.01E+00
3.00E+00
2.99E+00
Capacitance, pF
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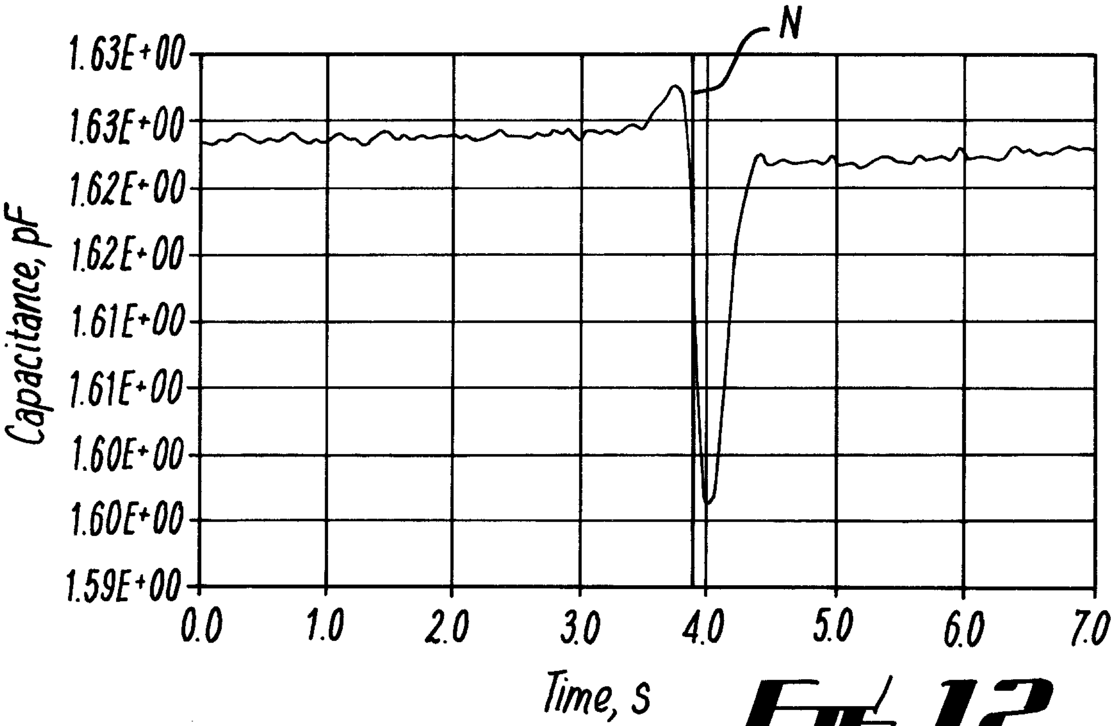
4.0
5.0
6.0
7.0
Time, s

FIG. 11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1.60E+00
1.59E+00
Capacitance, pF
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4.0
5.0
6.0
7.0
Time, s

FIG. 12

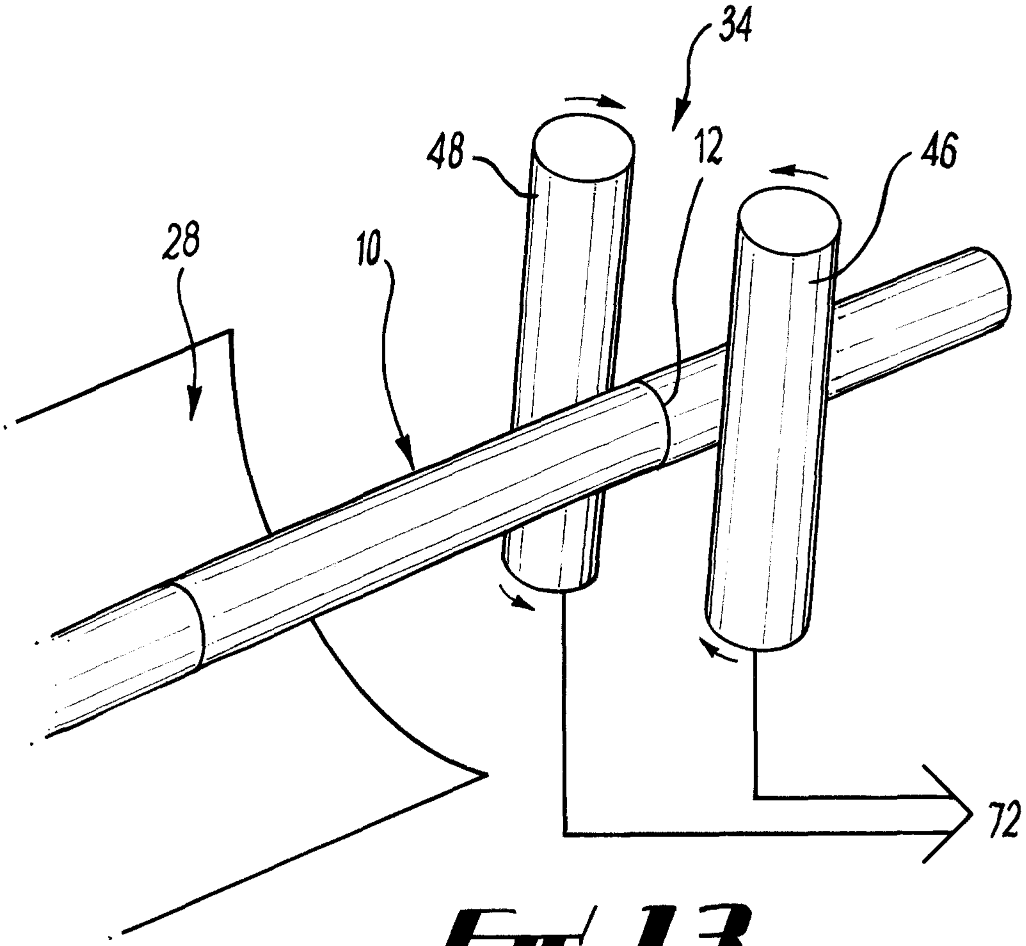

FIG. 13

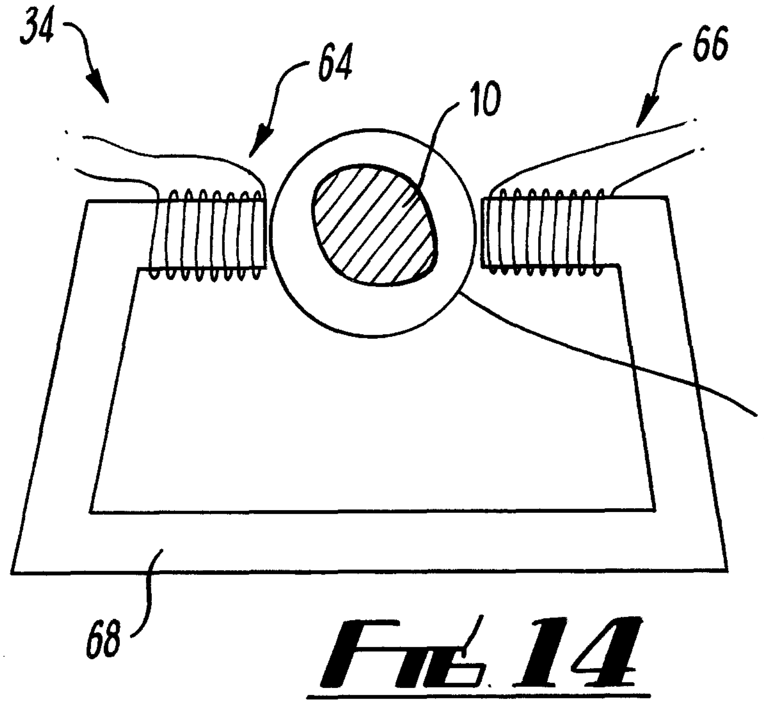

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/061388

A. CLASSIFICATION OF SUBJECT MATTER
INV. A01G7/00
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)
A01G A01H

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 practical, 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.
A	WO 86/06576 A1 (COMMW IND GASES [AU]) 20 November 1986 (1986-11-20) the whole document	1,10,14, 15,27,29
A	JP 3 070086 A (TOSHIBA CORP) 26 March 1991 (1991-03-26) * abstract	1,10,15, 27
A	WO 91/14356 A1 (UNIV QUEENSLAND [AU]; SUGAR EXPERIMENT STATIONS BOAR [AU]) 3 October 1991 (1991-10-03) * abstract	14,29
A	JP 6 129887 A (TOSHIBA CORP) 13 May 1994 (1994-05-13) * abstract	15,27

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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
27 October 2010	08/11/2010

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	Merckx, Alain

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/061388

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JP 6129887	A	13-05-1994	NONE			