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(71) Applicant: **KAHNE LIMITED** [NZ/NZ]; Level 3, DLA Phillips Fox Tower, 205 Queen Street, Auckland, 1010 (NZ).

(72) Inventors: **MALLINSON, Paul Benjamin**; 2 William Denny Avenue, Westmere, Auckland, 1022 (NZ). **BROOKS, Frank Welfare**; 32 Syracuse Place, Albany, Auckland, 0632 (NZ).

(74) Agents: **WEST-WALKER, Greg, J.** et al.; A J Park, PO Box 949, Wellington, 6140 (NZ).

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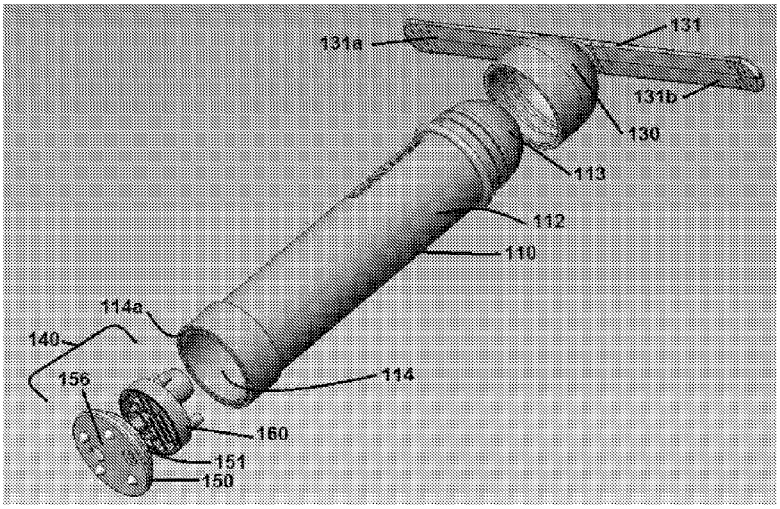


FIGURE 3

(57) Abstract: A rumen bolus for monitoring the physiological state of a rumen of a ruminant animal, may comprise a housing of a liquid crystal polymer material, a housing comprising an open end and a cap configured to couple to and substantially seal the open end, a pH sensing component comprising a body formed of a same material and integrally coupled with the housing, and/or a wireless transceiver having an antenna configured to provide uniform radiation about all axes of transmission/reception.

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"RUMEN BOLUS"

FIELD OF INVENTION

The invention relates to a device for monitoring the physiological condition of a ruminant, and in particular to a rumen bolus for cattle.

BACKGROUND

A rumen bolus is a device that is ingested into the rumen (stomach) of an animal, such as a cow or sheep for example, for monitoring the physiological state of the animal.

Kahne Ltd has developed a wireless rumen bolus that monitors in-rumen Ph, temperature, and pressure. The bolus can transmit data in real time or at a specific time of day, which is received by the end user in raw format. The bolus is mainly used as a scientific instrument for those involved in rumen research. It assists scientists by providing a continuous and real-time flow of in vivo measurements from cattle living under realistic commercial conditions. Such devices can be costly with a relatively short useful life and are not useful when deployed in a commercial or production scenario.

It is an object of the present invention to provide an improved rumen bolus or to at least provide the public with a useful choice.

SUMMARY OF THE INVENTION

In a first aspect the invention may broadly be said to consist of a device for monitoring the physiological state of a rumen of a ruminant animal, the device comprising:

a housing formed substantially from a liquid crystal polymer (LCP) material, and

one or more sensing components retained within the housing for obtaining information relating to a physiological state of the animal.

Preferably the housing is substantially sealed from an outside environment. Preferably the housing is substantially impermeable to gas, moisture and/or other contaminants present within the rumen.

Preferably in a preassembled state, the housing comprises an open end and a closed end. Preferably the bolus further comprises a cap element configured to couple the open end and substantially seal the open end of the housing in the assembled state. Preferably the cap element is formed from a LCP material. Preferably the open end of the housing comprises a groove about a peripheral edge of the open end for sealingly engaging a corresponding rib extending about the peripheral edge of the cap element. Preferably the rib and groove are sealingly coupled via ultrasonic welding.

In one embodiment the device comprises a pH sensing component to provide data indicative of pH within the rumen.

Preferably the pH sensing component comprises:

a body having an electrochemical cell therein formed from a reference electrode and a measurement electrode, the measuring electrode having a sensing surface protruding from and external to the body for exposure to a rumen environment, and

a voltage sensor electrically coupled between the measurement electrode and the reference electrode for measuring electrical potential indicative of a pH associated with the rumen environment to which the sensing surface is exposed.

Preferably the pH sensing component forms the body of the cap element.

Preferably the body comprises an outer reference cavity and an inner reference cavity for retaining a chemistry of the reference electrode therein. Preferably the voltage sensor is coupled to the measurement electrode and the electrochemistry of the inner reference cavity.

Preferably the outer reference cavity comprises a complex and/or convoluted path therein.

Preferably the measurement electrode is a glass electrode and the sensing surface protruding from and external to the body is a glass bulb of the glass electrode.

Preferably the body comprises an aperture extending through the outer reference cavity and external to the body. Preferably a salt bridge is retained within the aperture between the outer reference electrode and the external (rumen) environment. Preferably the salt bridge is a wick. Preferably an area of the aperture of the associated with the wick is approximately between $0.001mm^2$ and $0.5mm^2$, more preferably between approximately $0.01mm^2$ and $0.1mm^2$, and most preferably less than approximately $0.01mm^2$.

Preferably the body comprises a dividing wall between the outer reference cavity and the inner reference cavity. Preferably the body comprises an aperture through the dividing wall for retaining a salt bridge between the chemistry of the outer reference cavity and the chemistry of the inner reference cavity therein. Preferably the salt bridge is a wick. Preferably a plug is located within the aperture to retain the wick in place. Preferably an area of the aperture through the dividing wall is approximately between $0.001mm^2$ and $0.5mm^2$, more preferably between approximately $0.01mm^2$ and $0.1mm^2$, and most preferably less than approximately $0.01mm^2$.

Preferably the body is formed from two opposed parts.

Preferably the body is formed from a LCP material.

Preferably the two opposed parts are sealingly coupled via ultrasonic welding.

Preferably the first body part comprises a base and a receptacle extending from the base and open at an end opposing the base. Preferably the receptacle comprises a groove about a peripheral edge of the receptacle at the open end. Preferably the receptacle is divided by a wall into an outer reference section and an inner reference section corresponding to the outer reference cavity and the inner reference cavity with a recess in the wall corresponding to the aperture of the first dividing wall.

Preferably the second body part comprises a receptacle open at one end and having an outer reference section and an inner reference section, corresponding to the outer reference cavity and the inner reference cavity respectively, divided by a wall with a recess in the wall corresponding to the aperture of the dividing wall.

Preferably the receptacle of the first body and the receptacle of the second body comprise corresponding formations at the open end of each receptacle to enable sealable engagement of the open ends of the receptacles and thereby form the outer reference and the inner reference cavities of the body, and to thereby form the aperture of the dividing wall.

Preferably the open end of the receptacle of the first body part comprises one or more grooves and the open end of the receptacle of the second body part comprises one or more ribs for sealingly engaging the first and second body parts.

Preferably the one or more grooves extend about a peripheral edge of the receptacle of the first body part and along the wall dividing the first and second sections of the receptacle, and the one or more ribs extend about a peripheral edge of the receptacle of the second body part and along the wall dividing the first and second sections of the receptacle.

Preferably the receptacle of the first body part comprises one or more wall sections extending within the first section corresponding to the reference cavity and correspondingly the receptacle of the second body part comprises one or more wall sections extending within the first section corresponding to the reference cavity, to thereby form the complex

and/or convoluted path within the outer reference cavity when the first and second body parts are coupled.

Preferably each wall section of the first section of the receptacle of the first body part comprises a groove at an edge of the wall section, and each wall section of the first section of the receptacle of the second body part comprises a rib at an edge of the wall section for sealingly engaging the corresponding groove of the corresponding wall section when the first and second body parts are coupled.

Preferably the body of the pH sensor comprises an aperture through the body for sealingly accommodating the measuring electrode therein. Preferably the first body part comprises an aperture and the second body part comprises a corresponding aperture to form the aperture of the body for accommodating the measuring electrode therein. Preferably a peripheral edge of the aperture of the first body part comprises a groove and a peripheral edge of the aperture of the second body part comprises a corresponding rib configured to sealingly engage the groove of the aperture of the first body part.

Preferably the grooves of the first body part are sealingly coupled to the ribs of the second body part via ultrasonic welding.

Preferably the base of the first body part comprises a rib extending about a peripheral edge of the base in the same direction of extension as the receptacle.

Preferably the housing comprises an open end having a groove about a peripheral edge of the open end for sealingly engaging the corresponding rib extending about the peripheral edge of the base of the first body part of the pH sensing component. Preferably the rib and groove are sealingly coupled via ultrasonic welding.

Preferably the body of the pH sensing component is integral with the housing. Preferably the body of the pH sensing component is sealingly coupled to the housing via ultrasonic welding.

Preferably the device further comprises a temperature sensor within the housing to provide data indicative of temperature within the rumen.

Preferably the device further comprises a redox sensor within the housing to provide data indicative of the oxidation-reduction potential within the rumen.

Preferably the device further comprises a wireless transceiver to transmit/receive data or derived parameter(s) to and from a remote station.

Preferably the transceiver comprises an antenna. Preferably the antenna is configured to provide substantially uniform radiation about all axes of transmission/reception.

Preferably the antenna is a two-plane antenna having a first and second substantially orthogonal antenna sections. Preferably a first section of the antenna is oriented substantially orthogonal to a longitudinal axis of the housing and a second section is oriented substantially parallel to the longitudinal axis of the housing. Preferably the first section is a substantially annular section and the second section is substantially linear. Preferably the second section extends substantially centrally from the first section.

Preferably the device comprises a memory component in the housing for storing identification data unique to the device and measurement data obtained by the sensors of the device.

Preferably the housing of the device is shaped and sized to be retained within the rumen of the animal, and more preferably within the dorsal sac of the rumen. Preferably the device has an overall density of approximately less than or equal to $1g/cm^3$.

Preferably the device further comprises a retention mechanism for retaining the bolus within the rumen. Preferably retention mechanism comprises a wing structure at an end of the housing. Preferably the wing structure is at an end of the housing opposing the pH sensing component of the device. Preferably the wing structure is coupled to a closed end of the housing opposing the pH sensing component.

Preferably the housing is elongate along a longitudinal axis. Preferably the wing structure comprises one or more wings spanning substantially orthogonal to the longitudinal axis of the housing.

Preferably the wing structure further comprises a sleeved base configured to couple about the corresponding end of the housing. Preferably the wing structure comprises a pair of wings extending transversely and symmetrically from either side of the sleeved base.

Preferably the closed end of the housing comprises one or more ribs on an outer surface of the housing for engaging one or more corresponding grooves on an inner surface of the sleeve of the wing structure to secure the wing structure on the housing.

Preferably the wing structure is formed from a substantially flexible material, being relatively more flexible than the housing. The wing structure may be formed from a thermoplastic polymer such as Polypropylene, Nylon, Polyethylene or any other suitable alternative material.

In some embodiments the bolus also comprises a processor and memory associated with the processor storing one or more thermodynamic and/or physiological equations, the processor arranged to input the sensor array data into one or more or all of the equations to obtain as an output one or more parameters indicative of fermentation and/or animal digestive efficiency.

In a second aspect the invention may broadly be said to consist of a device for monitoring the physiological state of a rumen of a ruminant animal, the device comprising:

a housing, and

one or more sensing components retained within the housing for obtaining information relating to a physiological state of the animal, including a pH sensing component to provide data indicative of pH within the rumen, a body of the pH sensing component being formed of a same material and integrally coupled with the housing.

Preferably the body retains a reference electrode and a measurement electrode of an electrochemical cell therein.

Preferably the body comprises an outer reference cavity and an inner reference cavity for retaining chemistry of the reference electrode therein and an aperture for retaining the measurement electrode therein.

Preferably the pH sensing component further comprises a voltage sensor electrically coupled between the measurement electrode and the reference electrode for measuring electrical potential indicative of a pH associated with the rumen environment to which the sensing surface is exposed.

Preferably the body comprises an outer reference cavity and an inner reference cavity for retaining a chemistry of the reference electrode therein. Preferably the voltage sensor is coupled to the measurement electrode and the electrochemistry of the inner reference cavity.

Preferably the outer reference cavity comprises a complex and/or convoluted path therein.

Preferably the measurement electrode is a glass electrode and the sensing surface protruding from and external to the body is a glass bulb of the glass electrode.

Preferably the body comprises an aperture extending through the outer reference cavity and external to the body. Preferably a porous element is retained within the aperture to form a salt bridge between the outer reference electrode and the external (rumen) environment. Preferably the porous element is a plastic wick. Preferably an area of the aperture of the associated with the wick is approximately between 0.001mm^2 and 0.5mm^2, more preferably between approximately 0.01mm^2 and 0.1mm^2, and most preferably less than approximately 0.01mm^2, or
is approximately between 0.05mm^2 and 0.5mm^2, more preferably between approximately 0.1mm^2 and 0.3mm^2, and most preferably approximately 0.2mm^2.

Preferably the body comprises a dividing wall between the outer reference cavity and the inner reference cavity. Preferably the body comprises an aperture through the dividing wall. Preferably a wick is located and retained within the aperture of the dividing wall to provide a salt bridge between the chemistry of the outer reference cavity and the chemistry of the inner reference cavity. Preferably a plug is located within the aperture to retain the wick in place. Preferably an area of the aperture through the dividing wall is approximately between 0.001mm^2 and 0.5mm^2, more preferably between approximately 0.01mm^2 and 0.1mm^2, and most preferably less than approximately 0.01mm^2, or
is approximately between 0.05mm^2 and 0.5mm^2, more preferably between approximately 0.1mm^2 and 0.3mm^2, and most preferably approximately 0.2mm^2.

Preferably the body is formed from two opposed parts.

Preferably the body is formed form a LCP material.

Preferably the two opposed parts are sealingly coupled via ultrasonic welding.

Preferably the first body part comprises a base and a receptacle extending from the base and open at an end opposing the base. Preferably the receptacle comprises a groove about a peripheral edge of the receptacle at the open end. Preferably the receptacle is divided by a wall into an outer reference section and an inner reference section corresponding to the outer reference cavity and the inner reference cavity with a recess in the wall corresponding to the aperture of the first dividing wall.

Preferably the second body part comprises a receptacle open at one end and having an outer reference section and an inner reference section, corresponding to the outer reference

cavity and the inner reference cavity respectively, divided by a wall with a recess in the wall corresponding to the aperture of the dividing wall.

Preferably the receptacle of the first body and the receptacle of the second body comprise corresponding formations at the open end of each receptacle to enable sealable engagement of the open ends of the receptacles and thereby form the outer reference and the inner reference cavities of the body, and to thereby form the aperture of the dividing wall.

Preferably the open end of the receptacle of the first body part comprises one or more grooves and the open end of the receptacle of the second body part comprises one or more ribs for sealingly engaging the first and second body parts.

Preferably the one or more grooves extend about a peripheral edge of the receptacle of the first body part and along the wall dividing the first and second sections of the receptacle, and the one or more ribs extend about a peripheral edge of the receptacle of the second body part and along the wall dividing the first and second sections of the receptacle.

Preferably the receptacle of the first body part comprises one or more wall sections extending within the first section corresponding to the reference cavity and correspondingly the receptacle of the second body part comprises one or more wall sections extending within the first section corresponding to the reference cavity, to thereby form the complex and/or convoluted path within the outer reference cavity when the first and second body parts are coupled.

Preferably each wall section of the first section of the receptacle of the first body part comprises a groove at an edge of the wall section, and each wall section of the first section of the receptacle of the second body part comprises a rib at an edge of the wall section for sealingly engaging the corresponding groove of the corresponding wall section when the first and second body parts are coupled.

Preferably the body of the pH sensor comprises an aperture through the body for sealingly accommodating the measuring electrode therein. Preferably the first body part comprises an aperture and the second body part comprises a corresponding aperture to form the aperture of the body for accommodating the measuring electrode therein. Preferably a peripheral edge of the aperture of the first body part comprises a groove and a peripheral edge of the aperture of the second body part comprises a corresponding rib configured to sealingly engage the groove of the aperture of the first body part.

Preferably the grooves of the first body part are sealingly coupled to the ribs of the second body part via ultrasonic welding.

Preferably the base of the first body part comprises a rib extending about a peripheral edge of the base in the same direction of extension as the receptacle.

Preferably the housing comprises an open end having a groove about a peripheral edge of the open end for sealingly engaging the corresponding rib extending about the peripheral edge of the base of the first body part of the pH sensing component. Preferably the rib and groove are sealingly coupled via ultrasonic welding.

Preferably the body of the pH sensing component is sealingly coupled to the housing via ultrasonic welding.

In a third aspect the invention may broadly be said to consist of a device for monitoring the physiological state of a rumen of a ruminant animal, the device comprising:

a housing,

one or more sensing components retained within the housing for obtaining information relating to a physiological state of the animal, and

a wireless transceiver to transmit and receive data to and from a remote station, the transceiver having an antenna configured to provide substantially uniform radiation about all axes of transmission/reception.

Preferably the antenna is a two-plane antenna having a first and second substantially orthogonal antenna sections. Preferably a first section of the antenna is oriented substantially orthogonal to a longitudinal axis of the housing and a second section is oriented substantially parallel to the longitudinal axis of the housing. Preferably the first section is a substantially annular section and the second section is substantially linear. Preferably the second section extends substantially centrally from the first section.

In a fourth aspect, the invention may broadly be said to consist of a method of manufacturing a device configured to monitor the physiological state of a rumen of a ruminant animal, the method comprising the steps of:

forming a housing having a hollow interior with an open end and a closed end from LCP material,

forming a first part of a pH sensor housing from LCP material,

forming a second part of a pH sensor housing using LCP material,

ultrasonically welding the first part of the sensor housing to the second part of the sensor housing to form the sensor housing, and

ultrasonically welding the first part of the sensor to the housing of the bolus.

Preferably the method further comprises the step of inserting in the sensor housing electrochemistry associated with a reference electrode of the pH sensor.

Preferably the method further comprises, prior to the step of ultrasonically welding the first part of the sensor to the housing of the bolus, the step of coupling a measurement electrode to the sensor housing of the pH sensor.

Preferably prior to the step of ultrasonically welding the first part to the housing, one or more electronic monitoring components is/are inserted and retained within the hollow interior of the housing.

It will be appreciated any one or more of the above aspects can be provided in combination with any one or more of the above preferred or alternative embodiments or features.

The term "comprising" as used in this specification means "consisting at least in part of". When interpreting each statement in this specification that includes the term comprising", features other than that or those prefaced by the term may also be present. Related terms such as "comprise" and "comprises" are to be interpreted in the same manner.

It is intended that reference to a range of numbers disclosed herein (for example, 1 to 10) also incorporates reference to all rational numbers within that range (for example, 1, 1.1, 2, 3, 3.9, 4, 5, 6, 6.5, 7, 8, 9 and 10) and also any range of rational numbers within that range (for example, 2 to 8, 1.5 to 5.5 and 3.1 to 4.7) and, therefore, all sub-ranges of all ranges expressly disclosed herein are hereby expressly disclosed. These are only examples of what is specifically intended and all possible combinations of numerical values between the lowest value and the highest value enumerated are to be considered to be expressly stated in this application in a similar manner.

As used herein the term "and/or" means "and" or "or", or both.

As used herein "(s)" following a noun means the plural and/or singular forms of the noun.

This invention may also be said broadly to consist in the parts, elements and features referred to or indicated in the specification of the application, individually or collectively, and any or all combinations of any two or more said parts, elements or features, and where specific integers are mentioned herein which have known equivalents in the art to which this

invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

The invention consists in the foregoing and also envisages constructions of which the following gives examples only.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further described, by way of example only, and with reference to the drawings, in which:

Figure 1 is a perspective view of a preferred form bolus of the invention in the assembled form;

Figure 2 is a perspective view of the bolus of figure 1 showing hidden detail within the housing;

Figure 3 is a perspective view of the bolus of figure 1 showing the components in an exploded form;

Figure 4 is a top perspective view of an exploded housing for a pH sensing component in accordance with a preferred embodiment of the invention;

Figure 5 is a bottom perspective view of the housing of figure 4;

Figure 6 is a perspective view of the housing of figure 4 in the assembled form;

Figure 7 is a close up perspective view of the retention mechanism of the bolus of figure 1; and

Figure 8 is a perspective view of the electronics of the bolus of figure 1.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to figure 1, a preferred form device 100 is shown for monitoring the rumen environment and in particular for monitoring the physiological state of the animal while residing in the stomach or rumen of the animal. The device 100 (hereinafter also referred to as bolus 100) is preferably ingestible and configured to be retained within the rumen. The bolus 100 comprises a hollow body or housing 110 that is elongate and closed at both ends (at least in an assembled state of the bolus). As shown in figure 2, electronics 120 for monitoring and preferably reporting the physiological state of the animal within the rumen

are retained within the housing 110. In the assembled state of the bolus, an interior 111 of the housing is substantially sealed from the outside environment. To preserve the operation of the electronics and the accuracy of the readings, the bolus 100 and its housing 110 are formed to be substantially impermeable to gaseous and/or liquid chemicals and/or other substances present within the rumen of the animal. A retention mechanism 130 is provided at one end of the housing 110 for retaining the bolus 100 within the rumen. The retention mechanism 130 is in the form of a winged structure 130 having a pair of lateral wings 131a/b extending from the corresponding end of the housing 110. The wings 131 are substantially flexible to enable retraction and expansion during movement within the body of the animal (e.g. during ingestion and then within the rumen). At an opposing end of the housing 110, the bolus 100 further comprises a pH sensing element 140 for measuring the pH of the rumen environment to aid with the physiological monitoring.

In the preferred embodiment, the housing 110 is formed from a Liquid Crystal Polymer (LCP) based material. The housing 110 is preferably formed using injection moulding of an LCP material. It will be appreciated that the material from which the housing 110 is formed may be pure LCP or blended with any number of other materials. In some configurations the material comprises at least 5% LCP by mass. In some configurations the material comprises at least 10% LCP by mass. In some configurations the material comprises at least 20% LCP by mass. In some configurations the material comprises at least 50% LCP by mass. In some configurations the material comprises at least 85% LCP by mass. In a preferred embodiment the material comprises a 15% glass fibre filled LCP.

In the assembled state of the bolus 100, shown in figure 1, the housing 110 is closed at both ends 113 and 114. Both ends 113/114 of the housing 110 are also formed from an LCP material in the preferred embodiment. In particular, and referring to figure 3, end 113 is closed and formed integrally with the remainder of the housing 110 during the injection moulding process. End 114 is formed as an open end of the housing 110 during the injection moulding process and then later sealingly closed with a cap element or part 150 formed from a LCP material during assembly. The open end 114 enables the insertion and retention of the electronics 120 within the hollow interior 111 of the housing 110 during assembly of the bolus 100. After the insertion and retention of electronics 120 into the housing, the part 150 is sealingly coupled about open end 114 to close the end 114 of the housing 110. The part 150 is preferably integrally coupled to the end 114 of the housing. In the preferred embodiment, the part 150 is also formed from an LCP material, making it suitable to utilise ultrasonic welding to couple the part 150 to the housing 110 and integrate the part 150 with the end 114 of the housing 110.

In the preferred embodiment, the part 150 comprises an upstanding rib 151 about a peripheral edge of the part 150 that is configured to couple a corresponding groove 114a formed about the peripheral edge of the open end 114 of the housing 110. These components 151 and 114a are shown more clearly in figure 5. During coupling of the part 150 with the end 114, the rib 151 is inserted within and engages the groove 114a. To seal this junction and integrate the part 150 with the end 114 of the housing, the rib 151 is forced fully home into the groove 114a and in the process moulding to the shape of the groove 114a. To achieve this connection, an ultrasonic welding technique is utilised which is particular achievable and synergistic with LCP materials. After the coupling of the part 150 with the end 114, the housing 110 is sealed closed at both ends to form an outer wall 111 barrier suited for the in-rumen environment.

Referring to figures 4 and 5, in the preferred embodiment the part 150 forms the housing (or part of) for a pH sensing component 140 of the bolus 100. The pH sensing component comprises a reference electrode and a measurement electrode, both housed within a body of the component 140. The measurement electrode 170 comprises a sensing surface, bulb or probe 171 protruding from the body of the component 140. A voltage sensing element electrically couples between the measurement electrode 170 and the reference electrode to measure the pH of the external rumen environment. The chemistry retained within the sensing component 140 to form the reference and measurement electrodes will not be described in detail as it is not the subject of the invention. Any suitable solution/chemistry may be provided to build the appropriate electric circuit for sensing as is well known in the art. The mechanical structure of the sensing component 140 will now be described in detail in accordance with the preferred embodiment.

In the preferred configuration, the pH sensing component 140 comprises a two part housing or body 150 and 160. When coupled together, the two parts 150/160 form two cavities for the reference electrode chemistry and an aperture for the measurement electrode of the sensing component 140. Each part 150/160 of the body of the pH sensing component 140 comprises a hollow interior forming a receptacle 152/162 for the associated reference electrode chemistry to be retained therein. When the two body parts 150/160 are coupled, the outer walls of the two opposed and complementary receptacles 152/162 of the pH sensing component 140 form an enclosed chamber therein for sealingly retaining the reference electrode chemistry of the pH sensor. The reference electrode of the sensor 140 comprises two electrochemical half cells that are based on any chemistry known in the art of pH sensing or electrochemistry.

Each body part 150/160 comprises two cavities within the associated receptacle 152/162. A first outer reference cavity 153/163 of each receptacle 152/162 of the first and second body

parts 150/160 is intended to contain the outer reference electrode chemistry therein when the parts are coupled together and provides the interface to the rumen. A second inner reference cavity 154/164 of each receptacle 152/162 of the first and second body parts 150/160 is intended to contain the inner reference electrode chemistry therein when the parts are coupled together for coupling to the voltage sensor/electronics. The two cavities 153-154/163-164 of each body part 150/160 are separated and by a dividing wall 155/165 extending across the receptacle 152/162. In the preferred embodiment the wall 155/165 bisects the receptacle 152/162 but may alternatively divide the two sections at any other location within the receptacle to provide the required volume for each associated cell. In the preferred configuration, the first reference cavity 153/163 of the pH sensing component 140 comprises one or more upstanding wall sections 153a/163a for creating a complex and/or convoluted path from the outer reference cavity to the inner reference cavity (between aperture 157 and aperture 155a/165a) . In the configuration shown the two wall sections 153a/163a extend substantially parallel to one another and substantially parallel to the dividing wall 155/165 to form a substantially snaked, sinuous, serpentine or 'S' shaped cavity 153/163 for the reference cell. Alternative methods for creating a complex/convoluted path within the reference cavity may be employed, for example using any combination of one or more straight or curved walls that are parallel, orthogonal or at another angle to the dividing wall 155/165.

The body part 150 comprises a base portion 156 with the receptacle 152 extending from this base portion 156. An aperture 157 extends through the base portion 156 and into the outer reference cavity 153 of the receptacle 152. In the assembled state of the pH sensing component 140, a plug preferably fabricated from LCP is used to trap a wick and close the aperture 157. This provides a salt bridge between the outer reference chemistry and the external rumen environment. Preferably an area of the aperture 157 is approximately between 0.001mm^2 and 0.5mm^2, more preferably between approximately 0.01mm^2 and 0.1mm^2, and most preferably less than approximately 0.01mm^2. In some configurations the aperture size is approximately 0.04mm^2.

The dividing wall 155/165 of each receptacle 152/162 comprises a recess 155a/165a at the end of the complex/convoluted path of the first cavity 153/163. When the two body parts 150/160 are coupled together, the opposing recesses 155a/165a engage to form an aperture that connects the outer reference cavity 153/163 with the inner reference cavity 154/164 of the receptacle 152/162. In the preferred configuration a wick (not shown) is located within this aperture in the assembled state of the pH sensing component 140 to provide a salt bridge between the outer and inner reference chemistries or the reference electrode. The wick is retained within the aperture by a plug (not shown) sized to be sealingly accommodated within the aperture 155a/165a. The plug seals the aperture to

prevent contaminants from being transferred from the outer reference cell to the inner reference cell. Preferably an area of the aperture formed by the recesses 155a/165a is approximately between 0.001mm^2 and 0.5mm^2, more preferably between approximately 0.01mm^2 and 0.1mm^2, and most preferably less than approximately 0.01mm^2. In some configurations the aperture size is approximately 0.04mm^2.

An aperture 159/169 is provided in each of the body parts 150/160 for receiving and retaining a sensing/measurement electrode 170 of the pH sensing component 140 therethrough. Each aperture 159/169 extends transversely through the entire section of the body part 150/160. Referring also to figure 6, in the assembled state when the body parts 150/160 are coupled and the electrode 170 is inserted therethrough, a sensing surface or bulb 171 of the electrode 170 protrudes outside of the part 150 for exposure to the external rumen environment, and an opposing end 172 of the electrode 170 protrudes from the body part 160 to connect to electronics within the housing 110. A voltage sensing element is electrically connected at one terminal to the end 172 of the sensing probe 170 and at the other terminal to the inner reference cell in cavity 154/164 to provide a voltage signal indicative of the pH sensed at the bulb 171 of the electrode 170. The measurement electrode 170 is preferably a glass electrode 170 of any type as is known in the art of pH sensing. The glass electrode is coupled to the wall 159a/169a of the aperture 159/169 by means of an adhesive or other alternative. An annular seal/O-ring (not shown) optionally also with glue is preferably provided between the glass electrode 170 and the wall of the aperture 159/169 for sealingly retaining the glass electrode therein.

Complementary formations are provided on the two body parts 150 and 160 to couple the two body parts 150 and 160 of the pH sensing component 140 together. In the preferred embodiment, a peripheral edge of the receptacle 152 of the first body part 150 comprises one or more grooves 158 for receiving and retaining one or more corresponding ribs 168 on a peripheral edge of the receptacle 162 of the second body part 160. The one or more grooves 158 and corresponding ribs 168 are preferably continuous about the peripheral edges of the receptacles but may alternatively be discontinuous. In the preferred configuration, the one or more grooves 158 and ribs 168 also extend along the wall sections 153a/163a and the dividing wall 155/165 and about the peripheral edge of the probe aperture 159/169. A single groove 158 and single rib 168 preferably extend continuously along this entire path. In alternative embodiments, any combination of one or more grooves 158 and one or more corresponding ribs 168 may extend either continuously or discontinuously along adjacent surfaces of the two body parts 150 and 160, which could include any combination of the receptacle peripheral edges, the wall sections, and/or the peripheral edge of the wall aperture. The grooves may alternatively be located on part 160 or some on part 150 and some on part 160 and corresponding ribs may be located on part

150 or some on part 160 and some on part 150 respectively to achieve the required engagement. As described for the part 150 and the housing 110, the two parts 150 and 160 are preferably sealingly coupled to one another via ultrasonic welding.

In the preferred embodiment, the two parts 150 and 160 are formed from a LCP material. The housing 150/160 of pH sensing component 140 is preferably integrated with the housing 110 of the bolus 100 as described above with reference to part 150. In the preferred embodiment, the parts 150/160 are formed by injection moulding. The two parts are preferably integrally coupled via ultrasonic welding as described above.

Referring now to figures 1 and 7, the bolus 100 comprises a retention mechanism 130 at the closed end 113 of the housing 110. The retention mechanism 130 comprises a winged structure 131 having a pair of lateral wings 131a and 131b and a central sleeved base or sleeve 132 configured to (substantially sealingly) couple the end 113 of the housing 110 of the bolus 100. In the preferred embodiment, the winged structure comprises a pair of substantially linear, linearly aligned, and flat wings extending laterally from either side of the sleeve 132/housing 110. The application has found this particular wing structure to be particularly useful for retention of the bolus within the rumen of a cow, and to prevent regurgitation of the bolus 100. In alternative embodiments other winged structures may be employed having any number, orientation and profile of wings as is necessary for the intended application. The structure 130 is formed from a relatively flexible material, such as polypropylene, but alternatively from any other thermoplastic polymer, Nylon, Polyethylene or any other suitable alternative flexible material. This enables the wings to deform and flex as the bolus moves within the animal during ingestion and retention within the rumen. The inner wall of the sleeve 132 and the outer wall of the housing 110 at end 113 preferably comprise complementary formations for coupling the sleeve 132 to the housing 110. In the preferred embodiment, one or more ribs 115 are provided on outer wall of the housing 110 at end 113 for engaging one or more corresponding grooves 133 on the inner wall of the sleeve 132. The outer wall of the housing is preferably also rounded at end 113 to complement the rounded inner wall profile of the sleeve 132. An abutment or stop 116 is provided along the outer wall 112 of the housing 110 to engage the open end 134 of the sleeve 132 of the wing structure 130.

In the preferred embodiment, the housing 110, sleeve 132, and body parts 150 and 160 are all annular in profile. It will be appreciated that other external and/or internal shapes of any one or more of these components may be employed in alternative forms without departing from the scope of the invention.

A preferred application of the monitoring is for the monitoring of fermentation and/or process associated with the digestive efficiency of the animal. To monitor these aspects the bolus 100 is preferably configured to be retained within an upper part of the rumen, such as the dorsal sac. The bolus 100 is preferably shaped and sized to have an overall (assembled) density of substantially less than or equal to the density of water and/or substantially less than or equal to $1g/cm^3$. This enables the bolus to be retained in an upper part of the rumen or the dorsal sac. The bolus is light weight, preferably less than 100 grams, which along with buoyancy further assists it to be retained within the dorsal sac and not to fall through to the bottom of the rumen. In alternative embodiments or applications, the bolus 100 may be sized and shaped to be retained within any other location of the rumen or stomach of an animal, including for example the ventral sac or reticulum.

Referring to figure 2, the electronics 120 retained within the housing 110 comprise an electric circuit board 121 having coupled thereon any combination of one or more sensors, one or more power supplies, such as a battery 122, one or more processing units and associated memory components and/or one or more transmitters, receivers or transceivers. In addition to the pH sensing component 140, the bolus 100 may further comprises any combination of one or more other components including but not limited to temperature, redox, pressure, conductivity, sodium, potassium, chloride and ammonium sensors. The bolus 100 may send the data in raw format to a remote server which performs the processing and analysis of the data and/or an on-board processor in the bolus 100 may carry out such processing and transmit the derived parameters, or alternatively again the on-board processor may carry out some pre-processing before sending data to the server for further processing. The bolus 100 communicates to the server through wireless telemetry. The board 121 may be retained within the housing in any mechanical manner but is preferably coupled at one end to upstanding projections on an outer surface of part 160 of the pH sensing component 140 and at an opposing end to an orthogonal internal disc coupled to the inner periphery of the housing 110.

Referring to figure 8, the bolus 110 comprises a transceiver for sending/receiving information relating to and from a remote station external of the animal. The transceiver comprises an antenna for sending/receiving radiation of a predetermined frequency (such as 433MHz for example) to an associated transceiver of a remote station. The antenna 180 is preferably configured to provide a substantially uniform signal across multiple planes (preferably 3 axes) to enable substantially uniform transmission regardless of the orientation of the device. A two plane antenna 180 is provided within the housing at the end 121a of the circuit board 121. The two plane antenna 180 comprises first and second substantially orthogonal components 181 and 182 respectively. The first component 181 extends along the surface of the board 121 and the second component 182 extends along

an orthogonal disc 123 retained within the housing. The first components 181 comprises a pair of substantially linear legs 181a/b oriented substantially parallel to a longitudinal axis of the housing 110 and the second component 182 comprises a substantially annular shape extending from the first leg 181a about the outer edge of the disc 123 and to the second leg 181. The annular component 182 is oriented substantially perpendicular to the longitudinal axis of the housing 110. The applicant has found this configuration of a two plane antenna 180 to provide a desired distribution/pattern of radiation during transmission for the rumen monitoring application. Other transmitters/antenna configurations may be employed in alternative embodiments.

The foregoing description of the invention includes preferred forms thereof. Modifications may be made thereto without departing from the scope of the invention as defined in the accompanying claims.

CLAIMS:

1. A rumen bolus for monitoring the physiological state of a rumen of a ruminant animal, the rumen bolus comprising:

a housing comprising a liquid crystal polymer material, and

one or more sensing components retained within the housing for obtaining information relating to a physiological state of the animal.

2. A rumen bolus according to claim 1 wherein the housing is formed substantially from a liquid crystal polymer material.

3. A rumen bolus according to either claim 1 or claim 2 wherein the housing comprises an open end and a cap configured to couple to and substantially seal the open end.

4. A rumen bolus according to claim 3 wherein the cap also comprises a liquid crystal polymer material.

5. A rumen bolus according to any either claim 3 or claim 4 wherein the open end of the housing comprises a groove about a peripheral edge of the open end for sealingly engaging a corresponding rib about a peripheral edge of the cap.

6. A rumen bolus according to any one of claims 1 to 5 comprising a pH sensing component to provide data indicative of pH within the rumen.

7. A rumen bolus according to claim 6 wherein the pH sensing component comprises:

a body having an electrochemical cell therein formed from a reference electrode and a measurement electrode, the measuring electrode having a sensing surface protruding from and external to the body for exposure to a rumen environment, and

a voltage sensor electrically coupled between the measurement electrode and the reference electrode for measuring electrical potential indicative of a pH associated with the rumen environment to which the sensing surface is exposed.

8. A rumen bolus according to claim 6 or claim 7 wherein the pH sensing component is comprised in the cap.

9. A rumen bolus according to claim 8 wherein the cap comprises an outer reference cavity, and an inner reference cavity for retaining a chemistry of the reference electrode therein.

10. A rumen bolus according to claim 9 wherein the voltage sensor is coupled to the measurement electrode and the chemistry of the inner reference cavity.

11. A rumen bolus according to claim 9 or claim 10 wherein the outer reference cavity comprises a complex and/or convoluted path therein.

12. A rumen bolus according to any one of claims 9 to 11 wherein the cap comprises an aperture extending from the outer reference cavity to external to the cap.

13. A rumen bolus according to claim 12 wherein a salt bridge is retained within the aperture.

14. A rumen bolus according to any one of claims 9 to 13 wherein the cap comprises a dividing wall between the outer reference cavity and the inner reference cavity and an aperture through the dividing wall for retaining a salt bridge between a chemistry of the outer reference cavity and a chemistry of the inner reference cavity.

15. A rumen bolus according to any one of claims 8 to 14 wherein the cap comprises two opposed cap parts which together define within the cap the outer reference cavity and the inner reference cavity.

16. A rumen bolus according to claim 15 comprising a rib on one cap part and a grove on another cap part, which sealingly engage.

17. A rumen bolus according to any one of claims 1 to 16 further comprising a temperature sensor within the housing to provide data indicative of temperature within the rumen.

18. A rumen bolus according to any one of claims 1 to 17 further comprising a redox sensor within the housing to provide data indicative of the oxidation-reduction potential within the rumen.

19. A rumen bolus according to any one of claims 1 to 18 further comprising a wireless transceiver to transmit/receive data to a remote station.

20. A rumen bolus according to any one of claims 1 to 19 comprising a memory component in the housing for storing identification data unique to the device and measurement data obtained by the sensors of the device.

21. A rumen bolus according to any one of claims 1 to 20 shaped and sized to be retained within the dorsal sac of the rumen of a ruminant animal.

22. A rumen bolus according to any one of claims 1 to 21 which is elongate along a longitudinal axis and comprises one or more wings for retaining the bolus within the rumen spanning substantially orthogonal to the longitudinal axis of the housing.

23. A rumen bolus for monitoring the physiological state of a rumen of a ruminant animal, the rumen bolus comprising:

a housing comprising an open end and a cap configured to couple to and substantially seal the open end, and

one or more sensing components for obtaining information relating to a physiological state of the animal, including comprised in the cap a pH sensing component to provide data indicative of pH within the rumen.

24. A rumen bolus according to claim 23 wherein the pH sensing component comprises:

a body having an electrochemical cell therein formed from a reference electrode and a measurement electrode, the measuring electrode having a sensing surface protruding from and external to the body for exposure to a rumen environment, and

a voltage sensor electrically coupled between the measurement electrode and the reference electrode for measuring electrical potential indicative of a pH associated with the rumen environment to which the sensing surface is exposed.

25. A rumen bolus according to claim 24 wherein the cap comprises an outer reference cavity, and an inner reference cavity for retaining a chemistry of the reference electrode therein.

26. A rumen bolus according to claim 25 wherein the voltage sensor is coupled to the measurement electrode and the chemistry of the inner reference cavity.

27. A rumen bolus according to claim 24 or claim 25 wherein the outer reference cavity comprises a complex and/or convoluted path therein.

28. A rumen bolus according to any one of claims 25 to 27 wherein the cap comprises an aperture extending from the outer reference cavity to external to the cap.

29. A rumen bolus for monitoring the physiological state of a rumen of a ruminant animal, comprising:

a housing, and

one or more sensing components retained within the housing for obtaining information relating to a physiological state of the animal, including a pH sensing component to provide data indicative of pH within the rumen, a body of the pH sensing component being formed of a same material and integrally coupled with the housing.

30. A rumen bolus for monitoring the physiological state of a rumen of a ruminant animal, the device comprising:

a housing,

one or more sensing components retained within the housing for obtaining information relating to a physiological state of the animal, and

a wireless transceiver to transmit and receive data to and from a remote station, the transceiver having an antenna configured to provide substantially uniform radiation about all axes of transmission/reception.

31. A rumen bolus according to claim 30 wherein the antenna is a two-plane antenna having a first and second substantially orthogonal antenna sections.

32. A rumen bolus according to claim 31 wherein a first section of the antenna is oriented substantially orthogonal to a longitudinal axis of the housing and a second section is oriented substantially parallel to the longitudinal axis of the housing.

33. A rumen bolus according to claim 32 wherein the first section is a substantially annular section and the second section is substantially linear.

34. A rumen bolus according to claim 33 wherein the second section extends substantially centrally from the first section.

35. A method of manufacturing a device configured to monitor the physiological state of a rumen of a ruminant animal, the method comprising the steps of:

forming a housing having a hollow interior with an open end and a closed end from LCP material,

forming a first part of a pH sensor housing from LCP material,

forming a second part of a pH sensor housing using LCP material,

welding the first part of the sensor housing to the second part of the sensor housing to form the sensor housing, and

welding the first part of the sensor to the housing of the bolus.

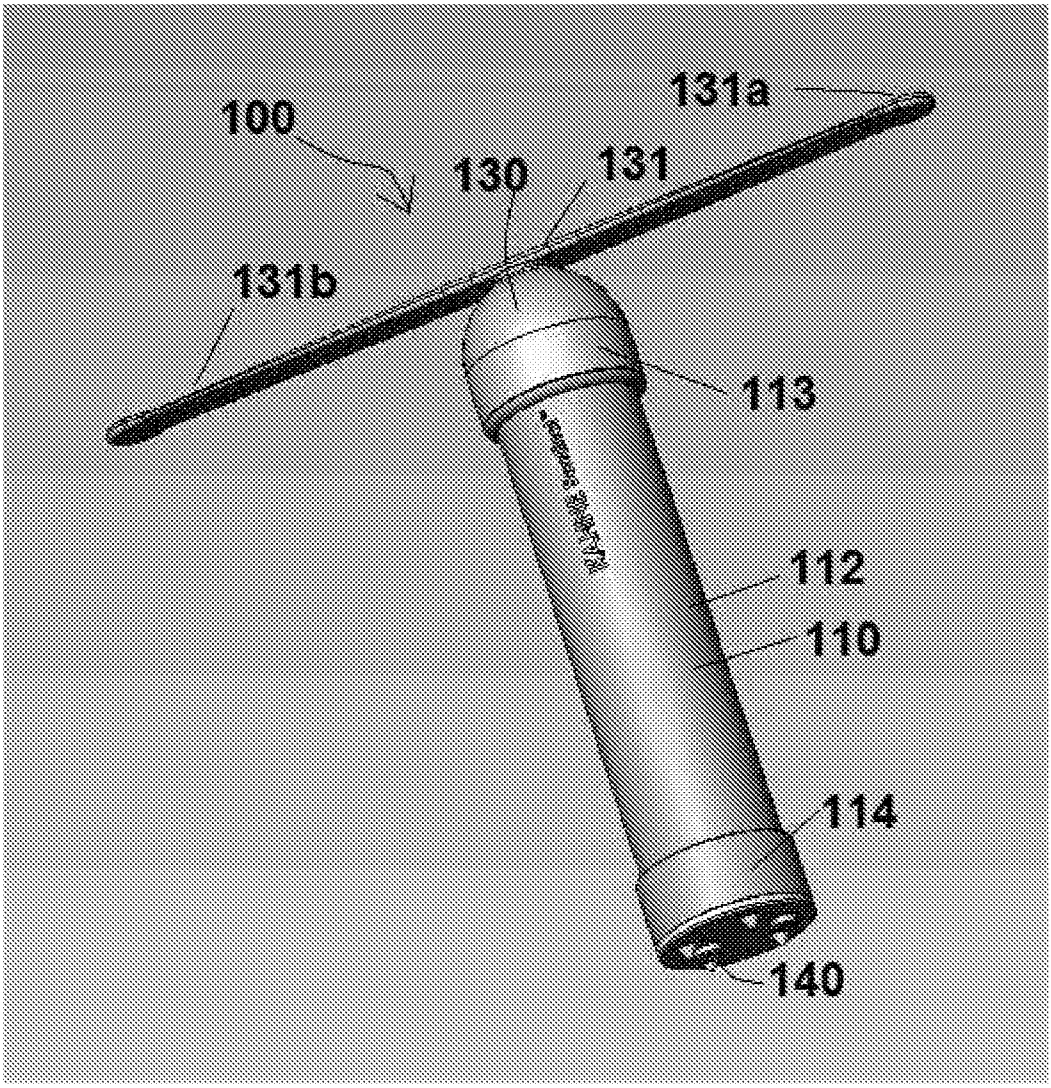


FIGURE 1

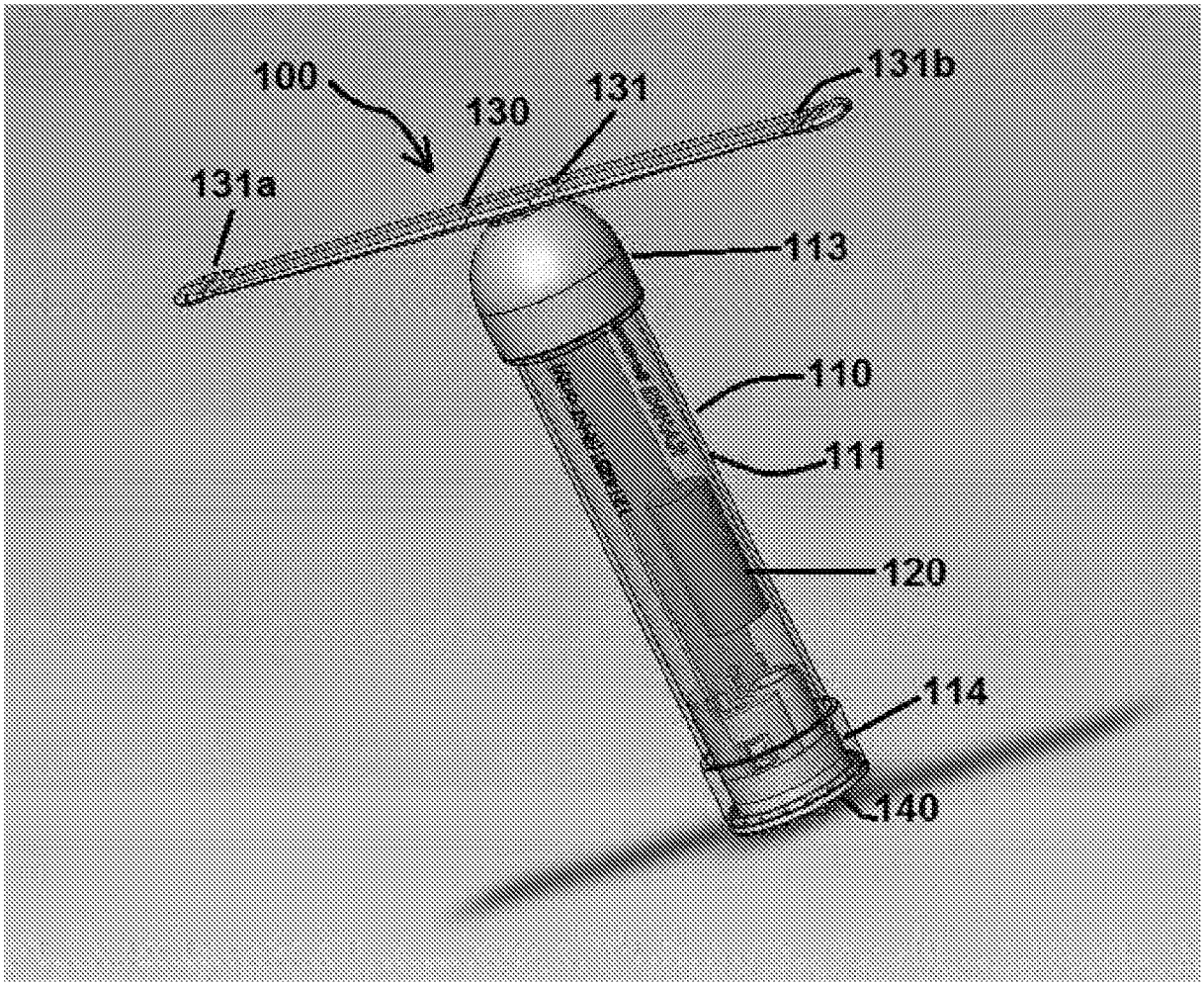


FIGURE 2

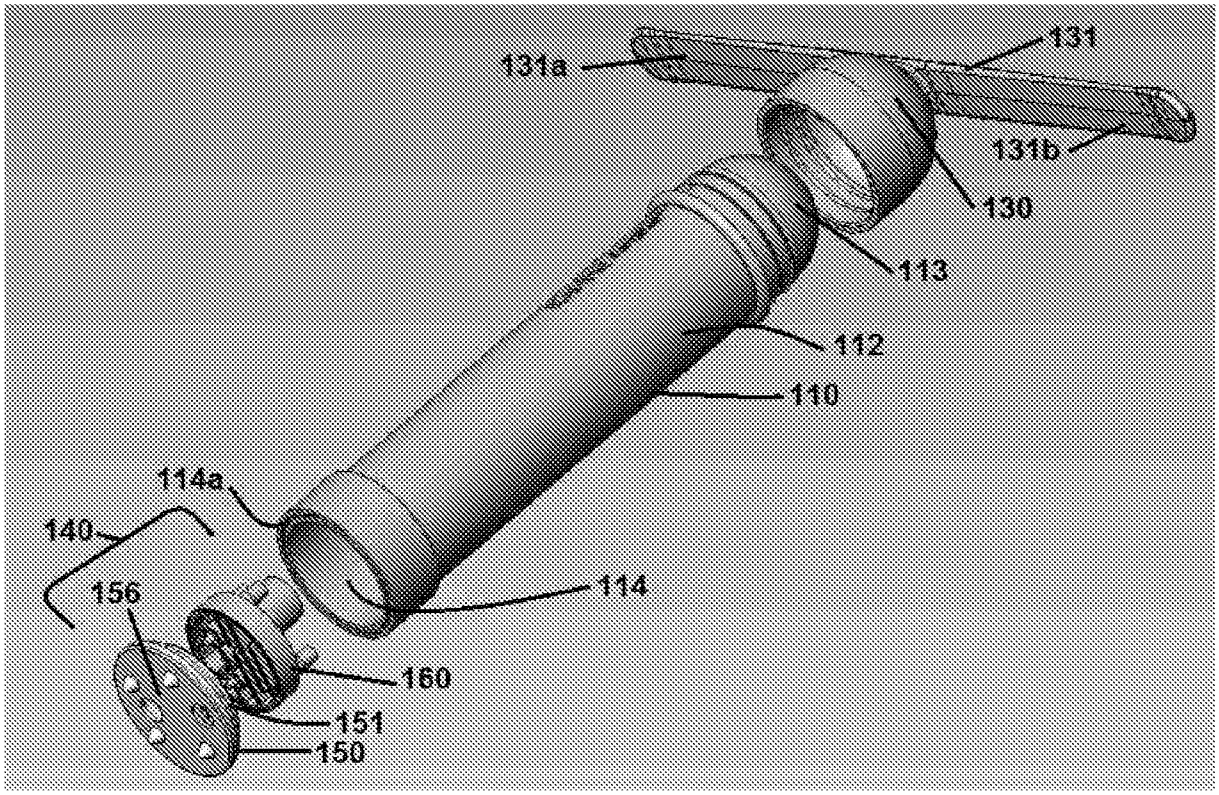


FIGURE 3

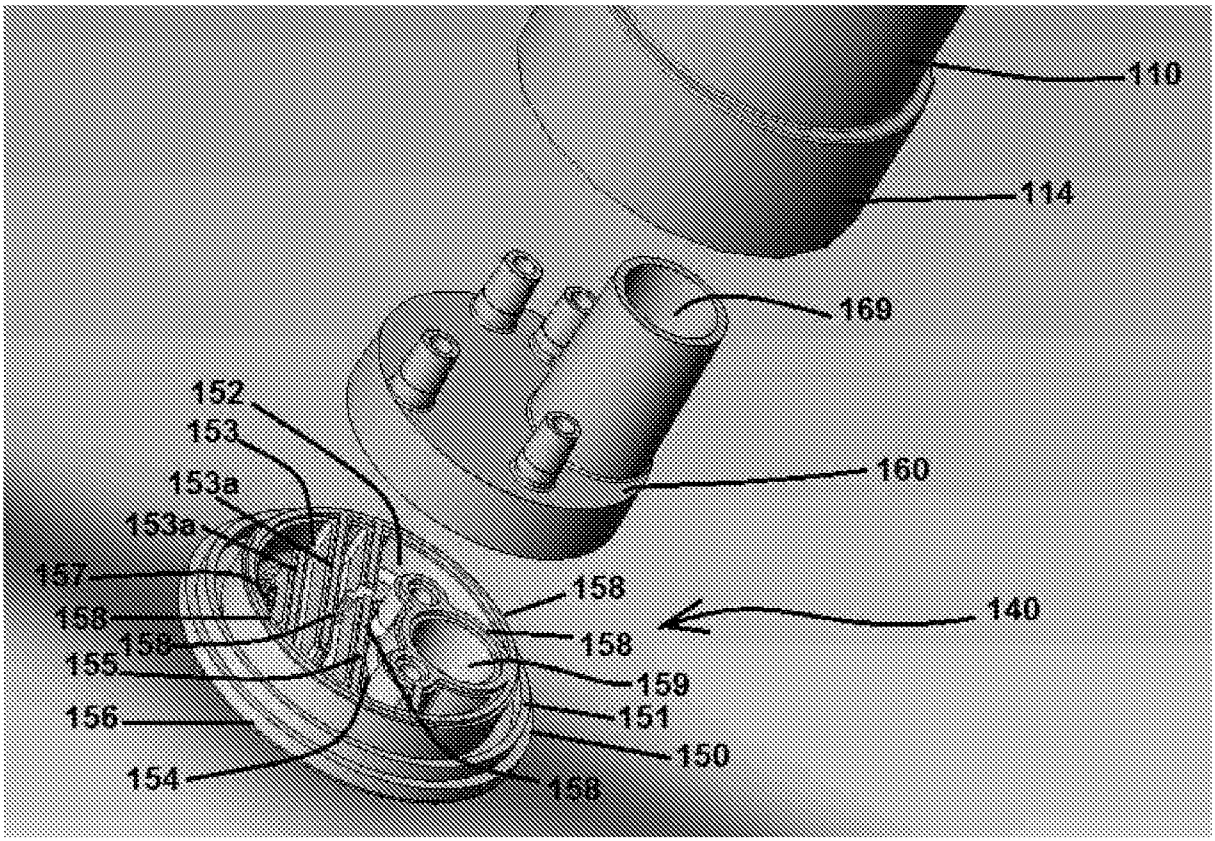

110
114
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152
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153a
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154
158

FIGURE 4

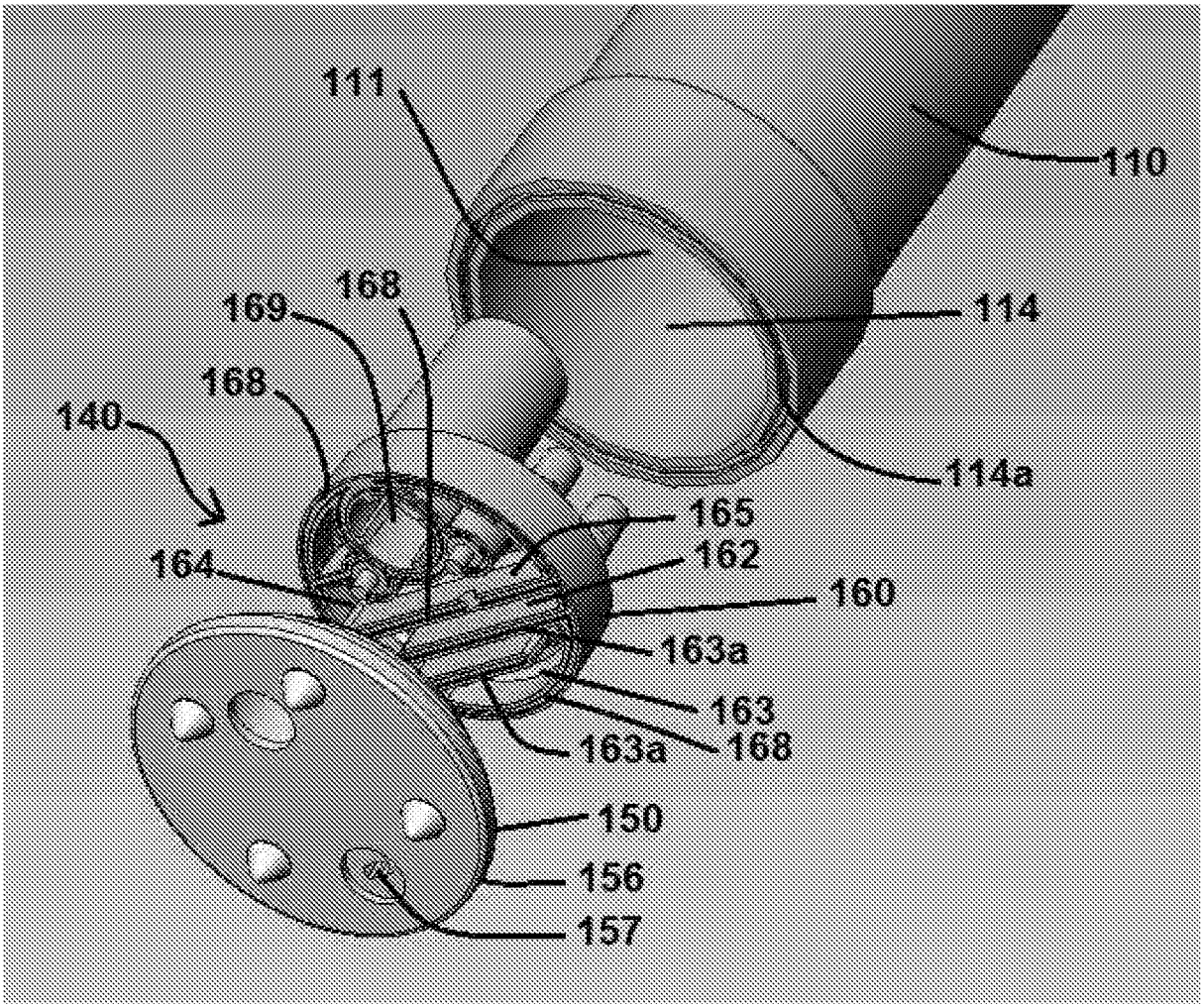

111
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163a
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157

FIGURE 5

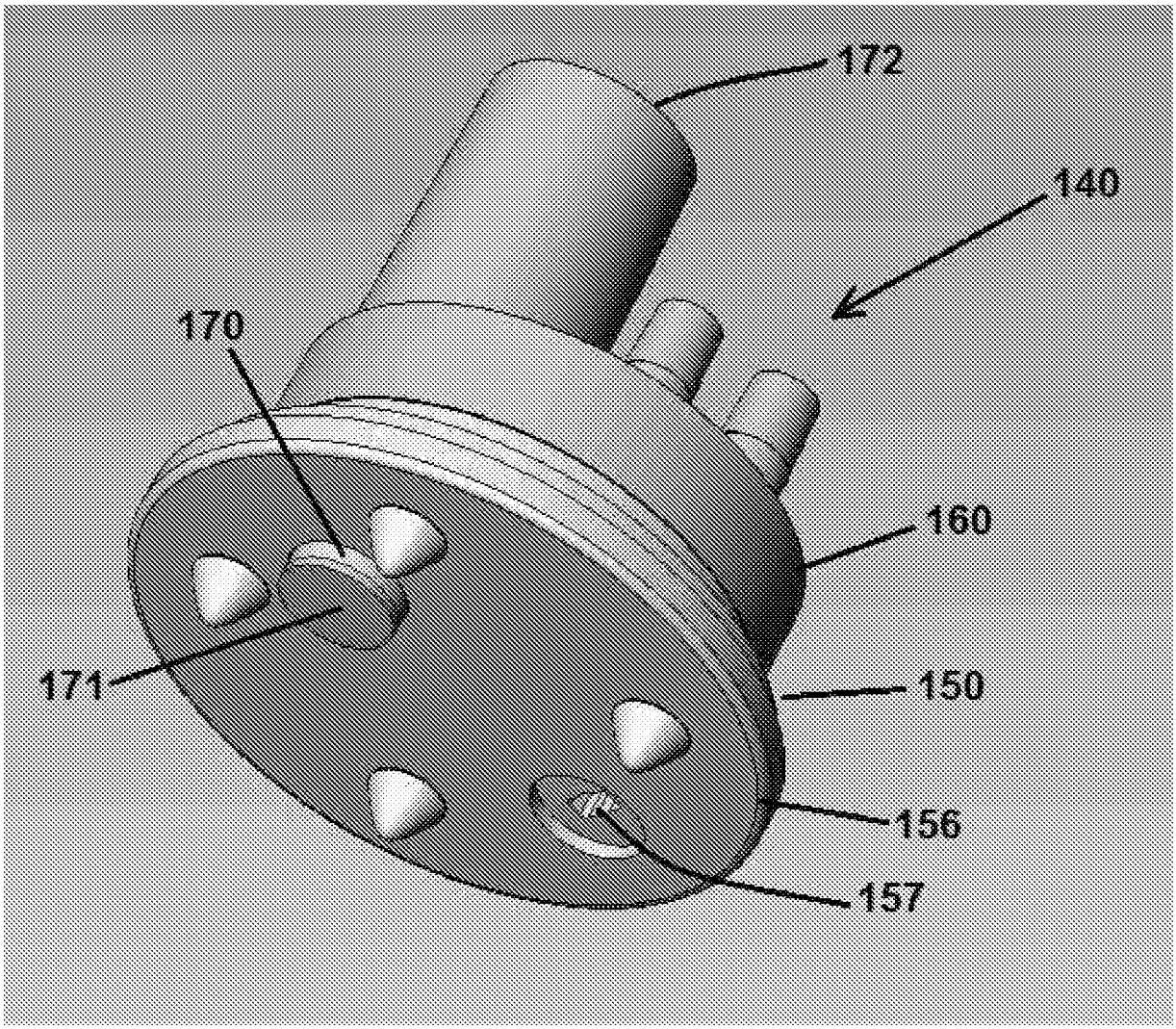


FIGURE 6

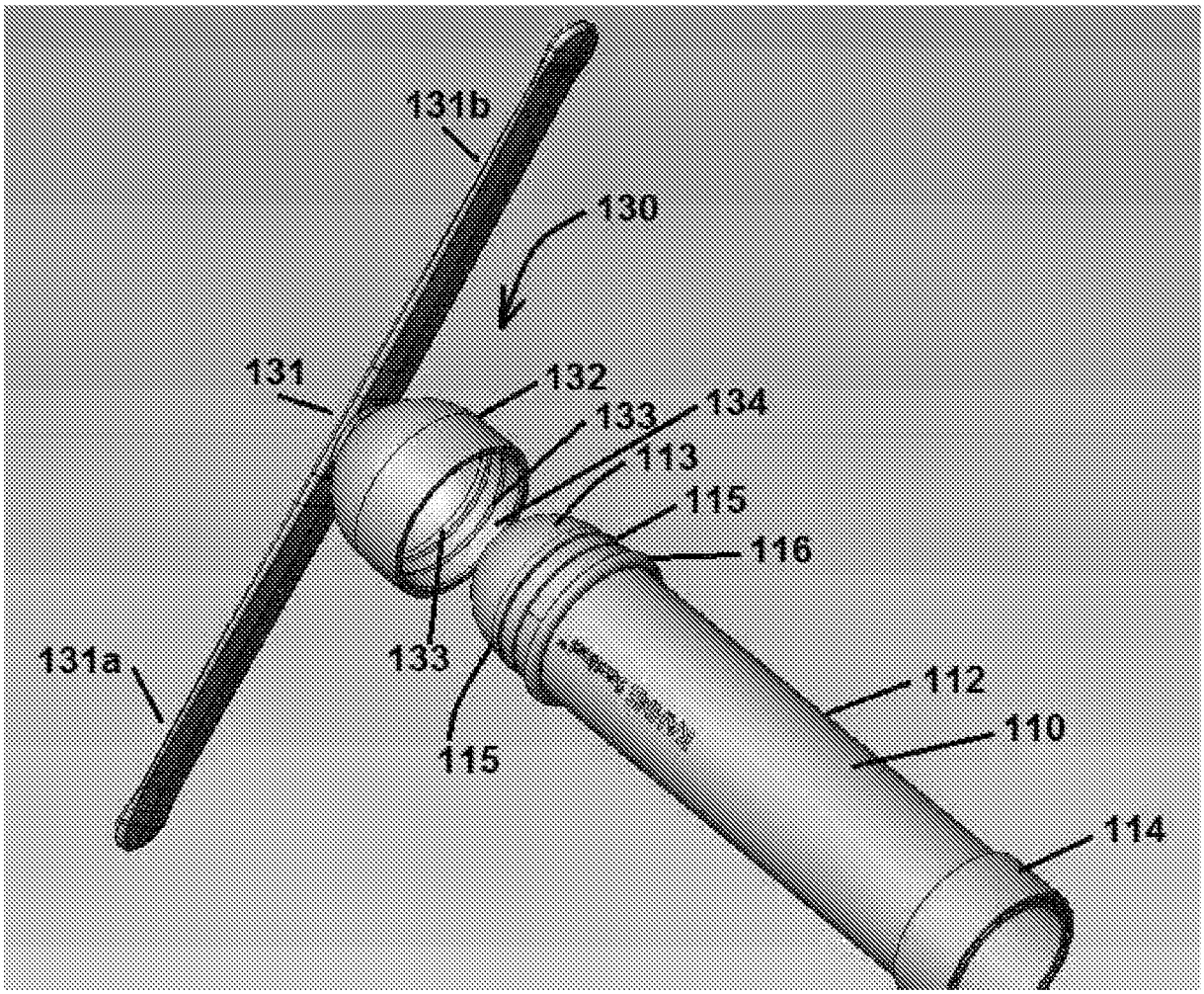


FIGURE 7

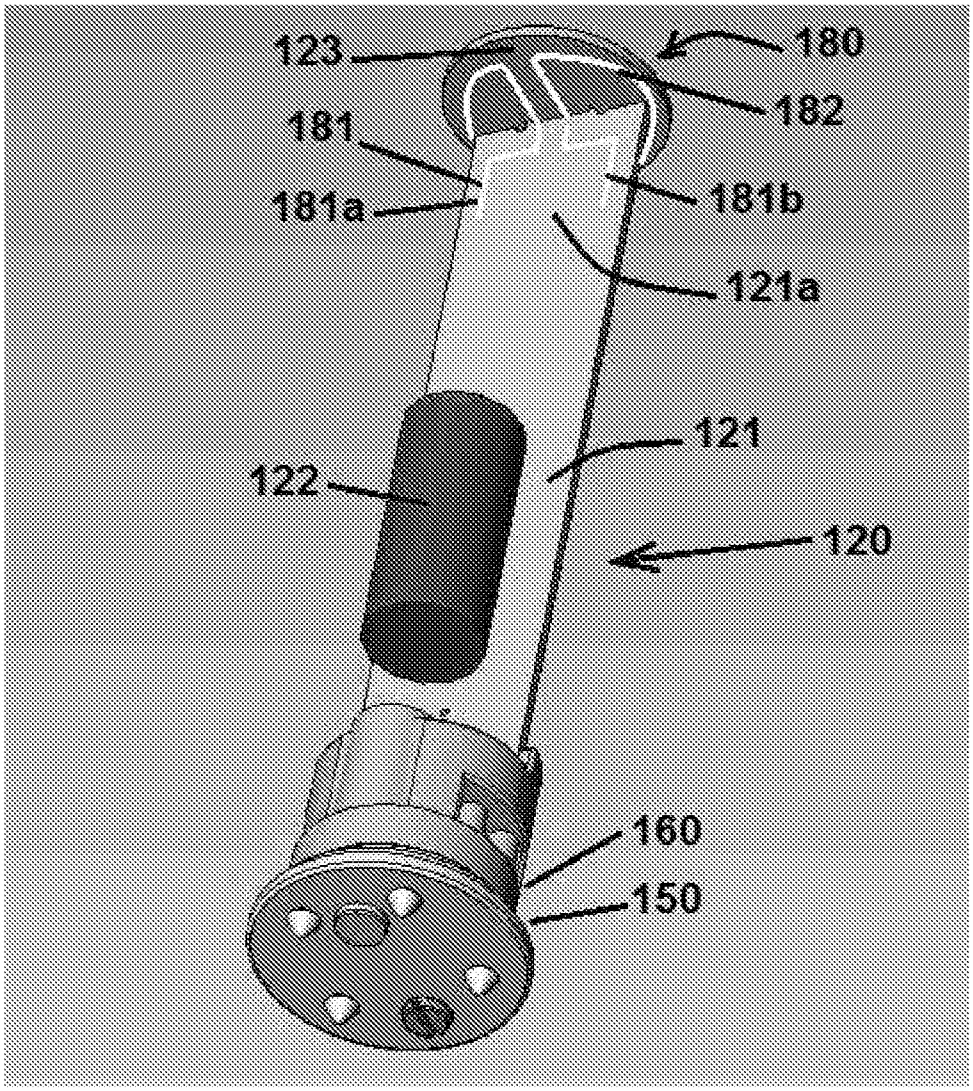


FIGURE 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2014/000116

A. CLASSIFICATION OF SUBJECT MATTER

A61B 5/07 (2006.01) A01K 11/00 (2006.01)

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)

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)

WPI, EPODOC: CPC A61B5/073, A01K11/007 & Keywords (rumen, bolus, liquid crystal, cap, sensor) and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 October 2014	08 October 2014
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Galvin Koh AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832985

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/NZ2014/000116**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0236500 A1 (HODGES et al.) 02 October 2008 FIGS 1-5; paragraphs [0047-0059]	1-35
X	EP 2438812 A1 (INCORPORATED NATIONAL UNIVERSITY IWATE UNIVERSITY) 11 April 2012 FIGS 7-10; paragraphs [0078-0174]	1-35
X	WO 2012/054085 A2 (BELLA TECHNOLOGIES, LLC) 26 April 2012 FIGS 4 and 5; pages 12-15	1-35
A	WO 2012/047150 A1 (DELAVAL HOLDING AB) 12 April 2012 FIGS 3-5; pages 7-10	6,7 and 24

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/NZ2014/000116**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2008/0236500 A1	02 October 2008	None	
EP 2438812 A1	11 April 2012	JP 5569911 B2	13 Aug 2014
		US 2012088988 A1	12 Apr 2012
		WO 2010147175 A1	23 Dec 2010
WO 2012/054085 A2	26 April 2012	CA 2852208 A1	26 Apr 2012
		EP 2629602 A2	28 Aug 2013
		US 2013197323 A1	01 Aug 2013
WO 2012/047150 A1	12 April 2012	EP 2624683 A1	14 Aug 2013
		US 2013178721 A1	11 Jul 2013
		US 8694091 B2	08 Apr 2014

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.