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(54) **APPARATUS, METHOD AND SYSTEM FOR DETERMINING A PHYSIOLOGICAL CONDITION WITHIN A MAMMAL**

(52) **U.S. Cl. 600/301; 600/551; 600/591**

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(57) **ABSTRACT**

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A system, method and apparatus for determining a physiological condition within a mammal based on pH and/or temperature measurements. In one aspect, the invention is directed to an apparatus for measuring a physiological condition within a mammal comprising: a probe for insertion into a body lumen of the mammal, the probe housing a first circuit board operably coupling a pH sensor for measuring pH within the body lumen and generating a pH signal indicative of the measured pH, a memory device storing parametric data unique to the pH sensor, and a first interface connector located at a proximal portion of the probe; a handle for manipulating the probe, the handle housing a second circuit board operably coupling a microprocessor for processing the pH signal and generating an output signal based on the processing of the pH signal, an indicia device for communicating the output signal generated by the microprocessor, and a second interface connector; the probe connected to the handle in a manner that allows the probe and handle to be repetitively engaged and disengaged from each other; and wherein when the probe is connected to the handle, the first and second interface connectors are in operable connection so that the microprocessor can retrieve the parametric data from the memory device of the probe and receive the pH signal.

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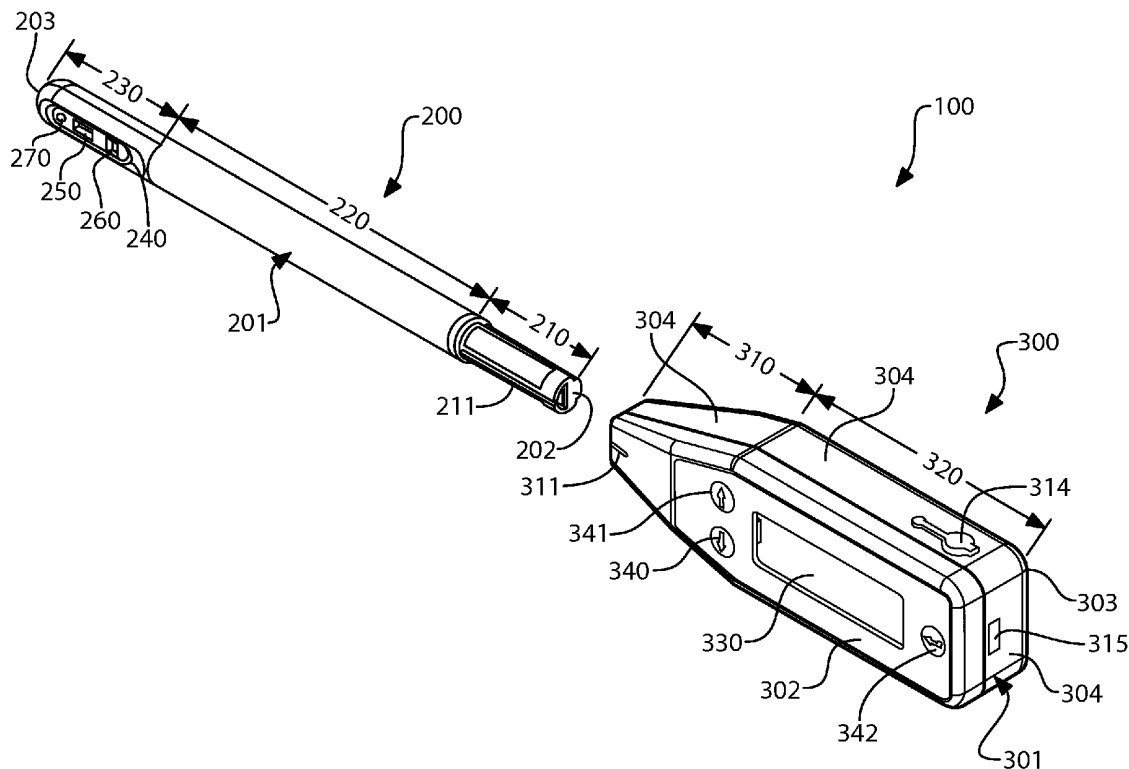
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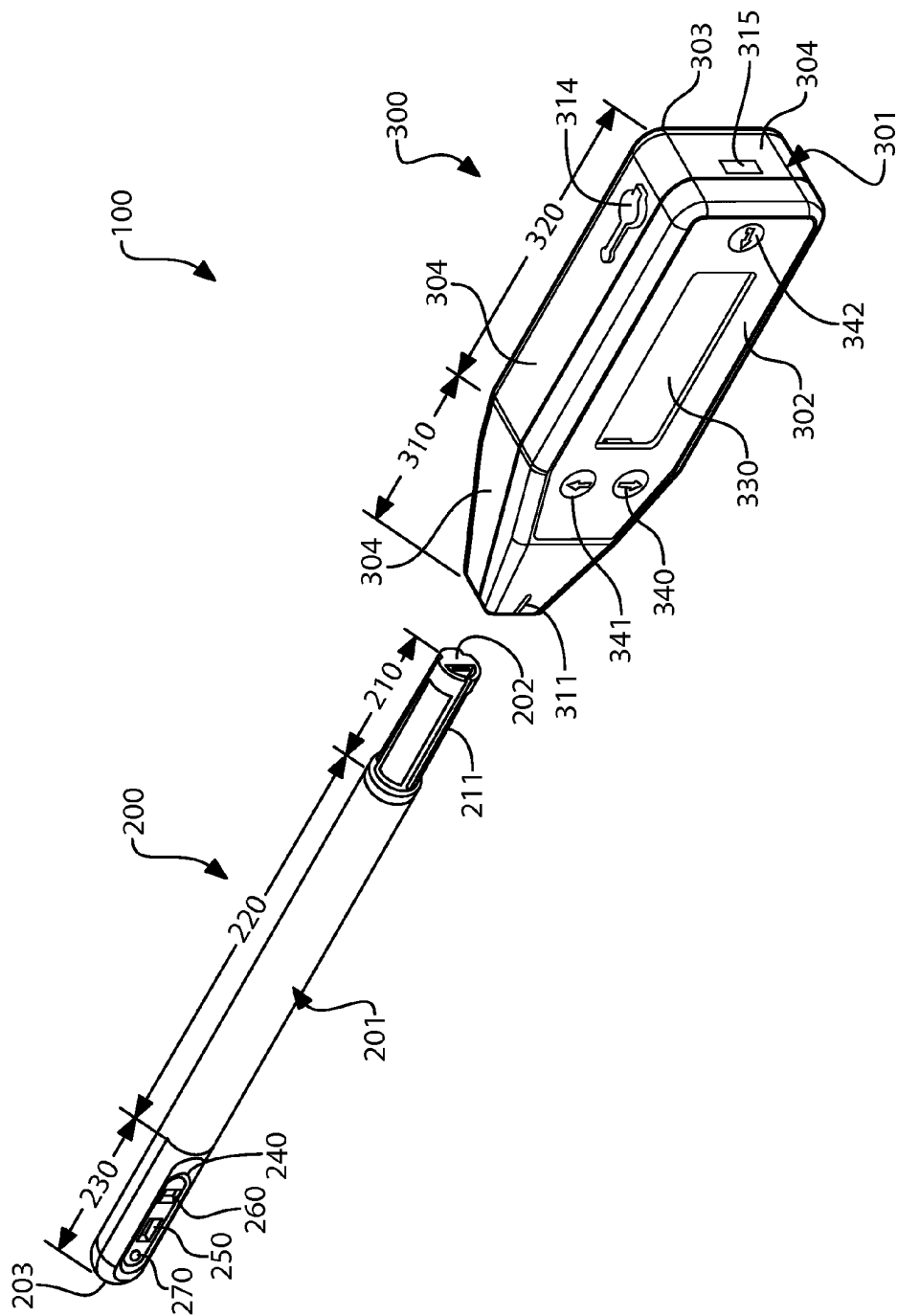


FIG. 1

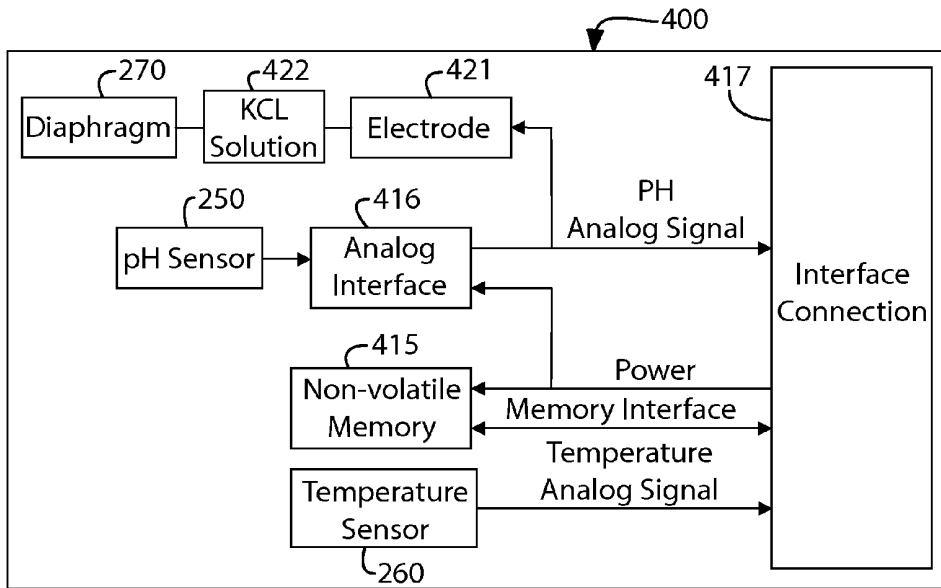


FIG. 2

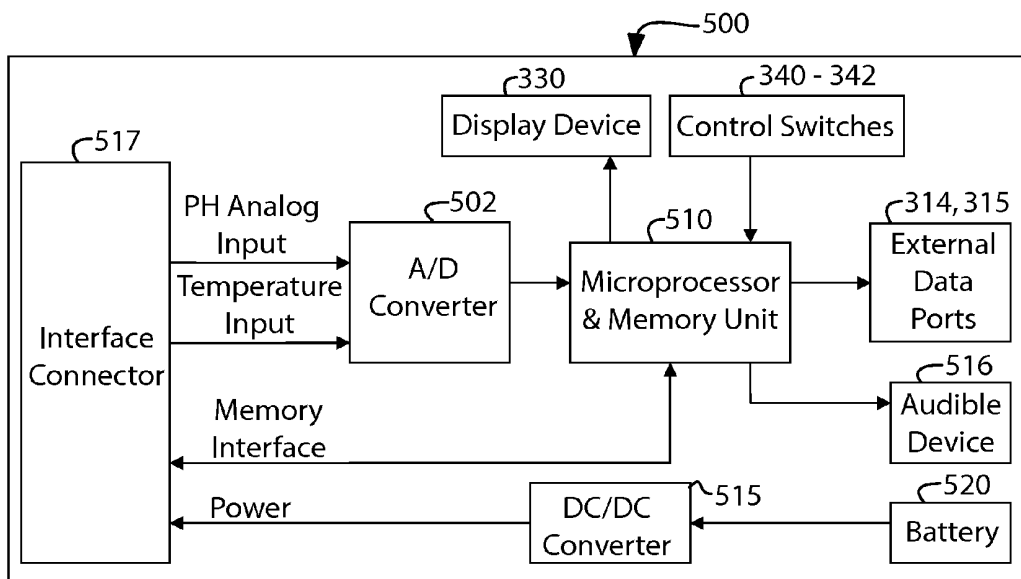


FIG. 3

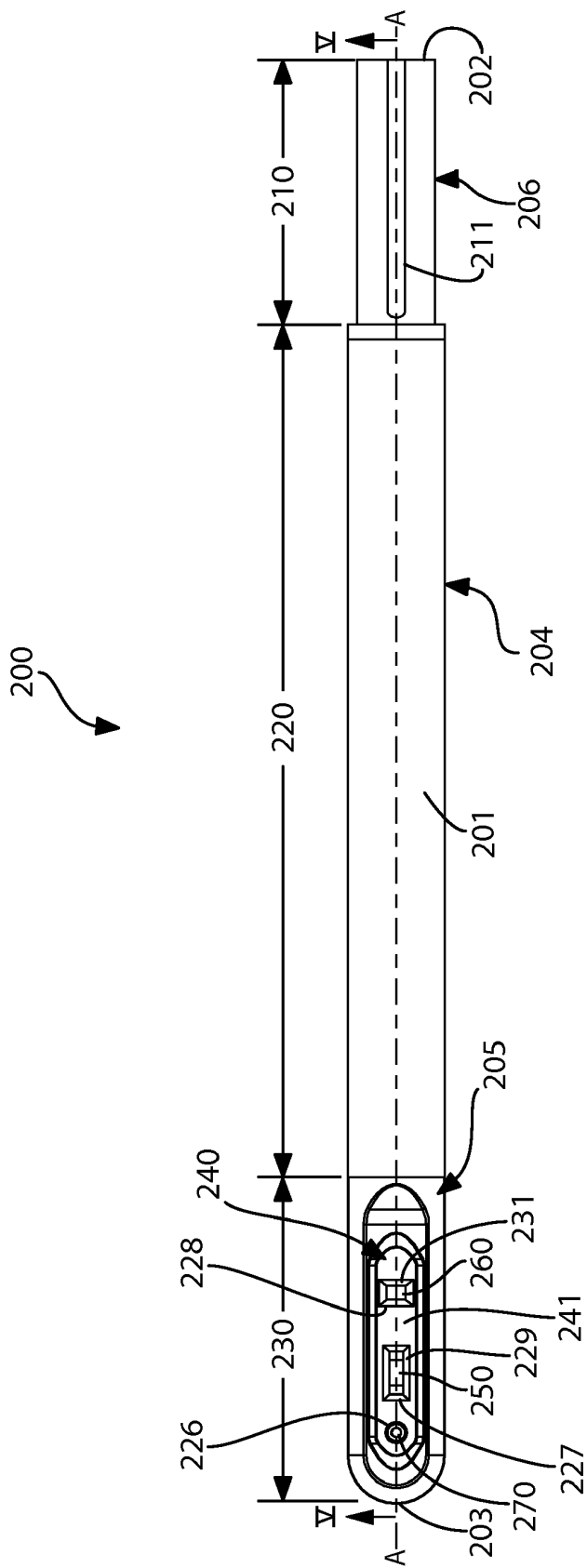


FIG. 4

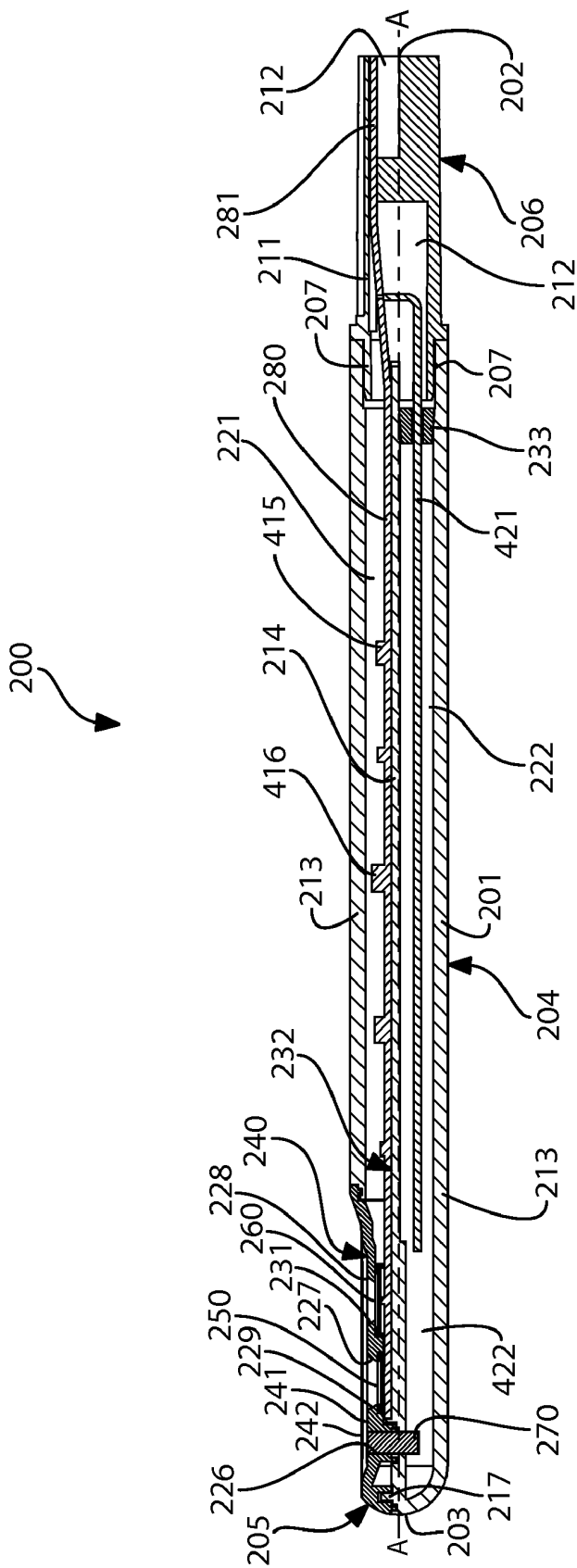


FIG. 5

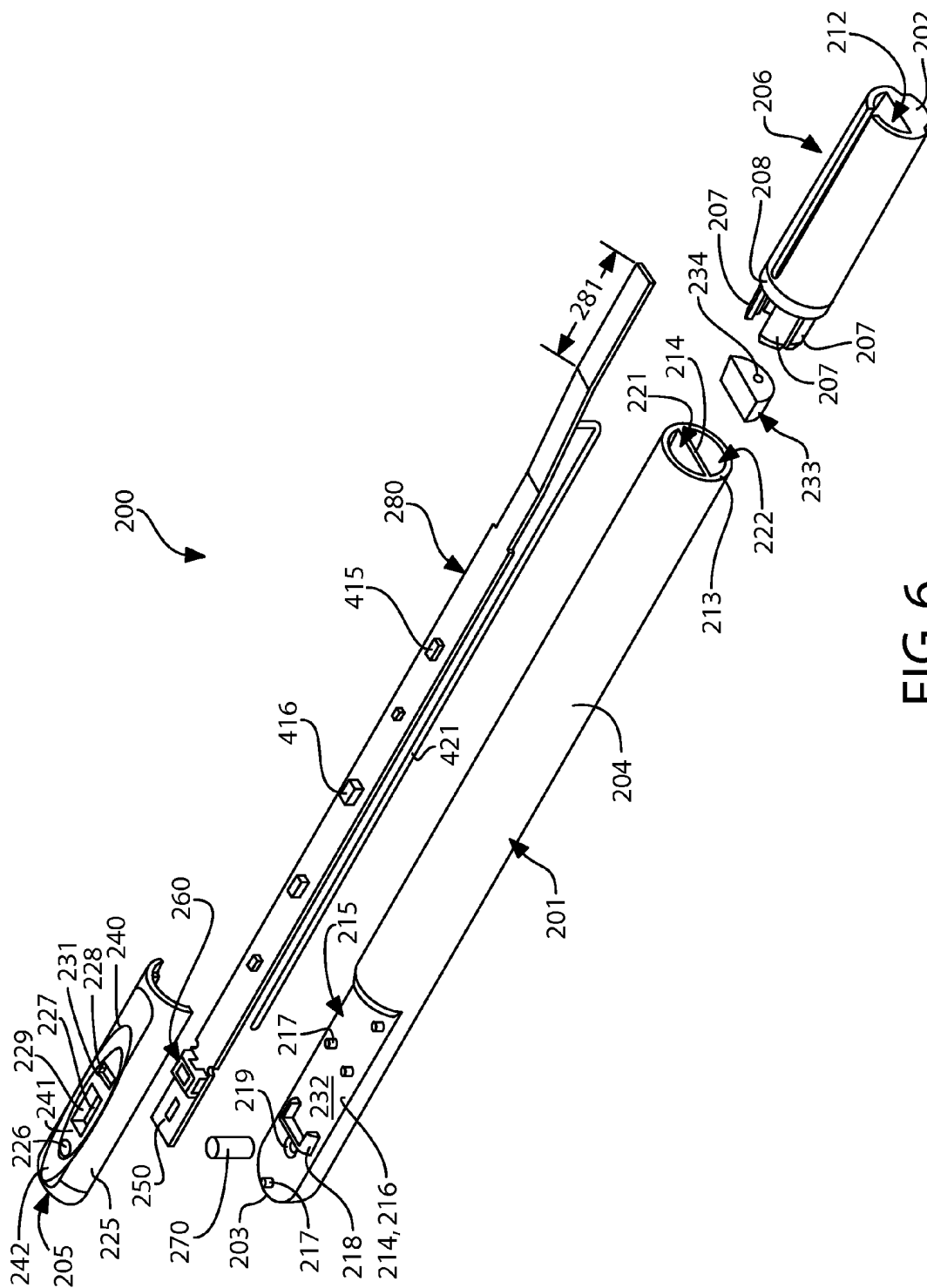


FIG. 6

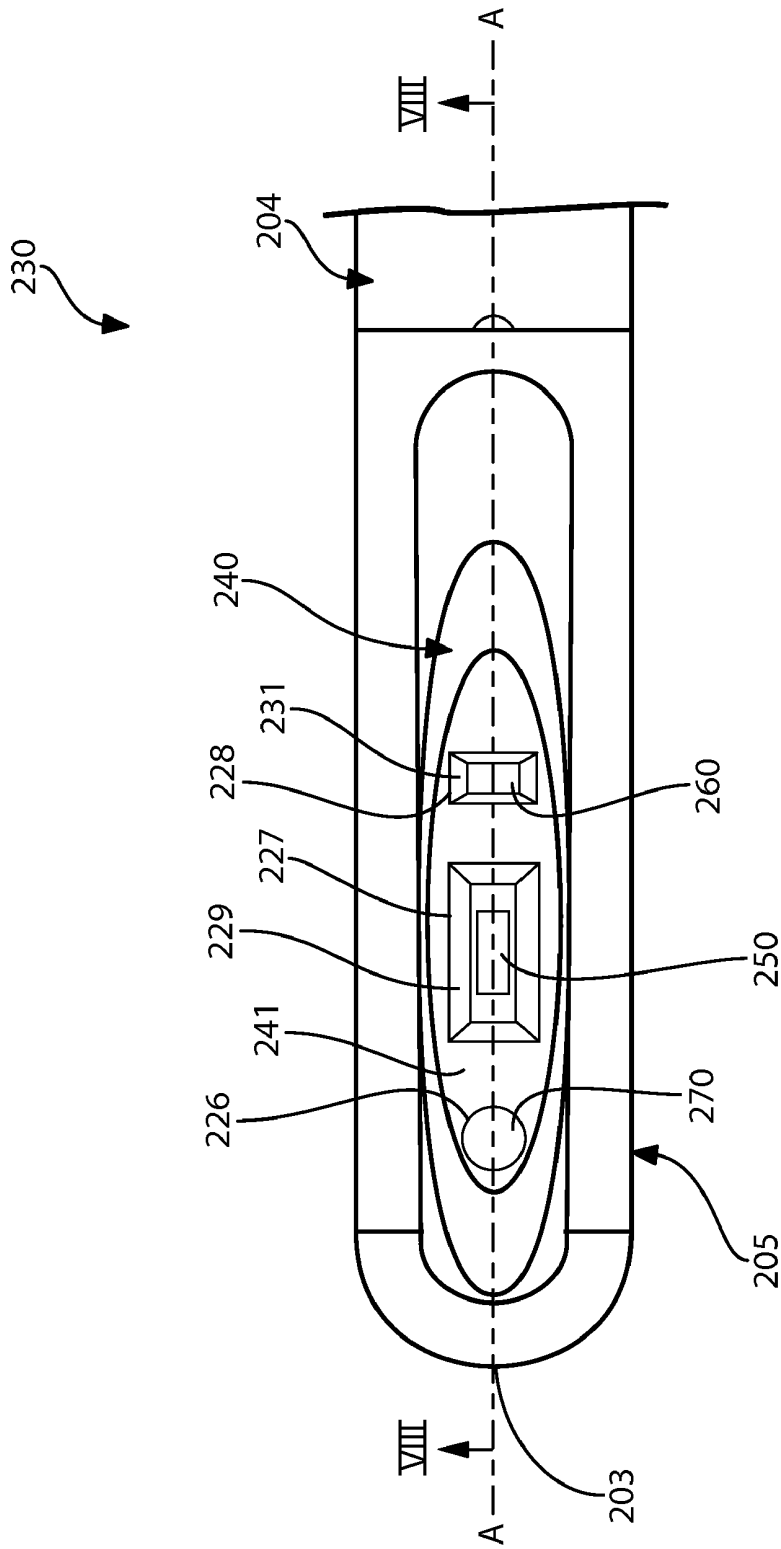


FIG. 7

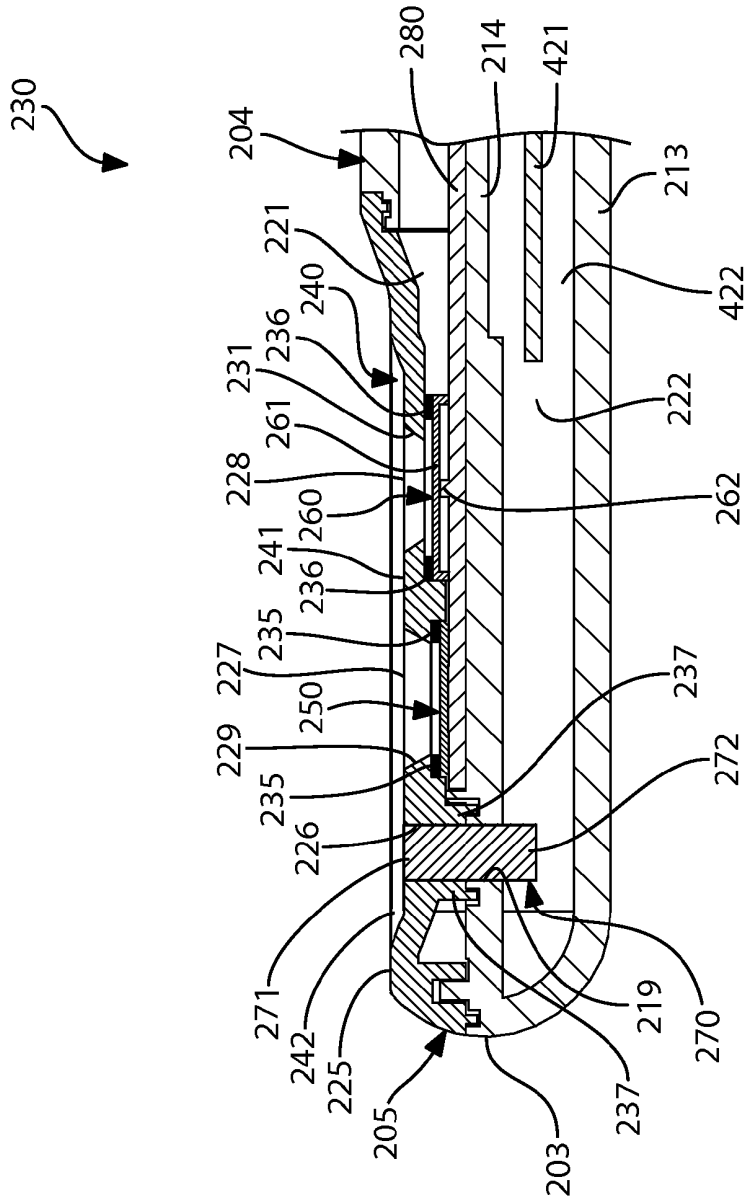


FIG. 8

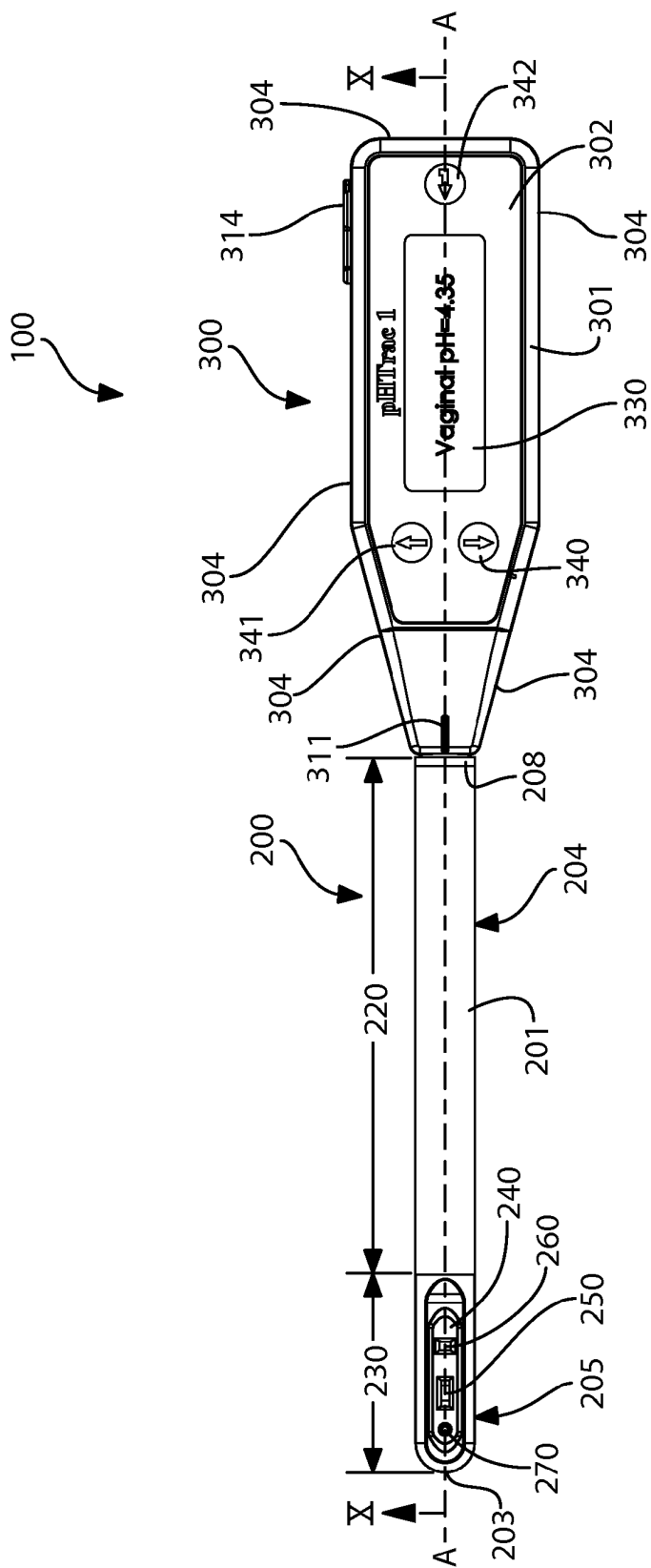


FIG. 9

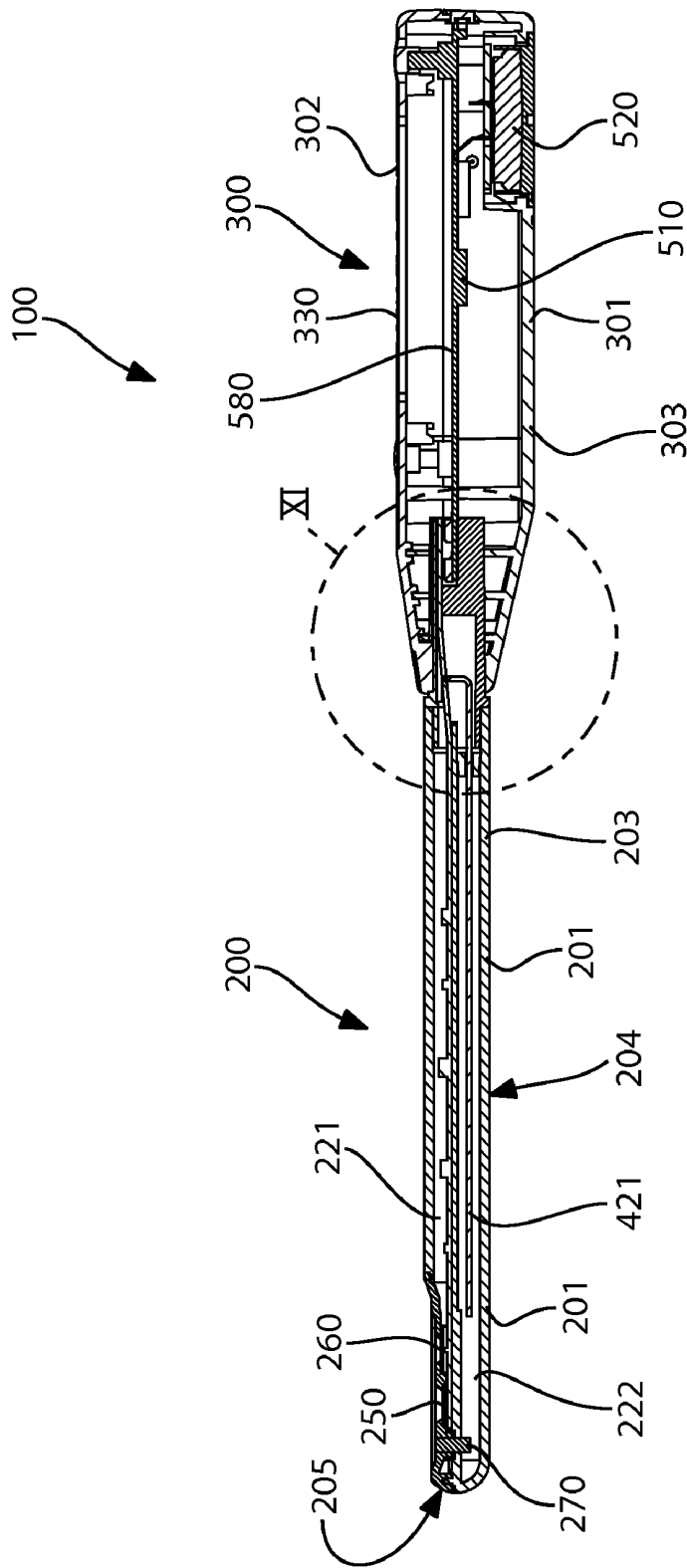


FIG. 10

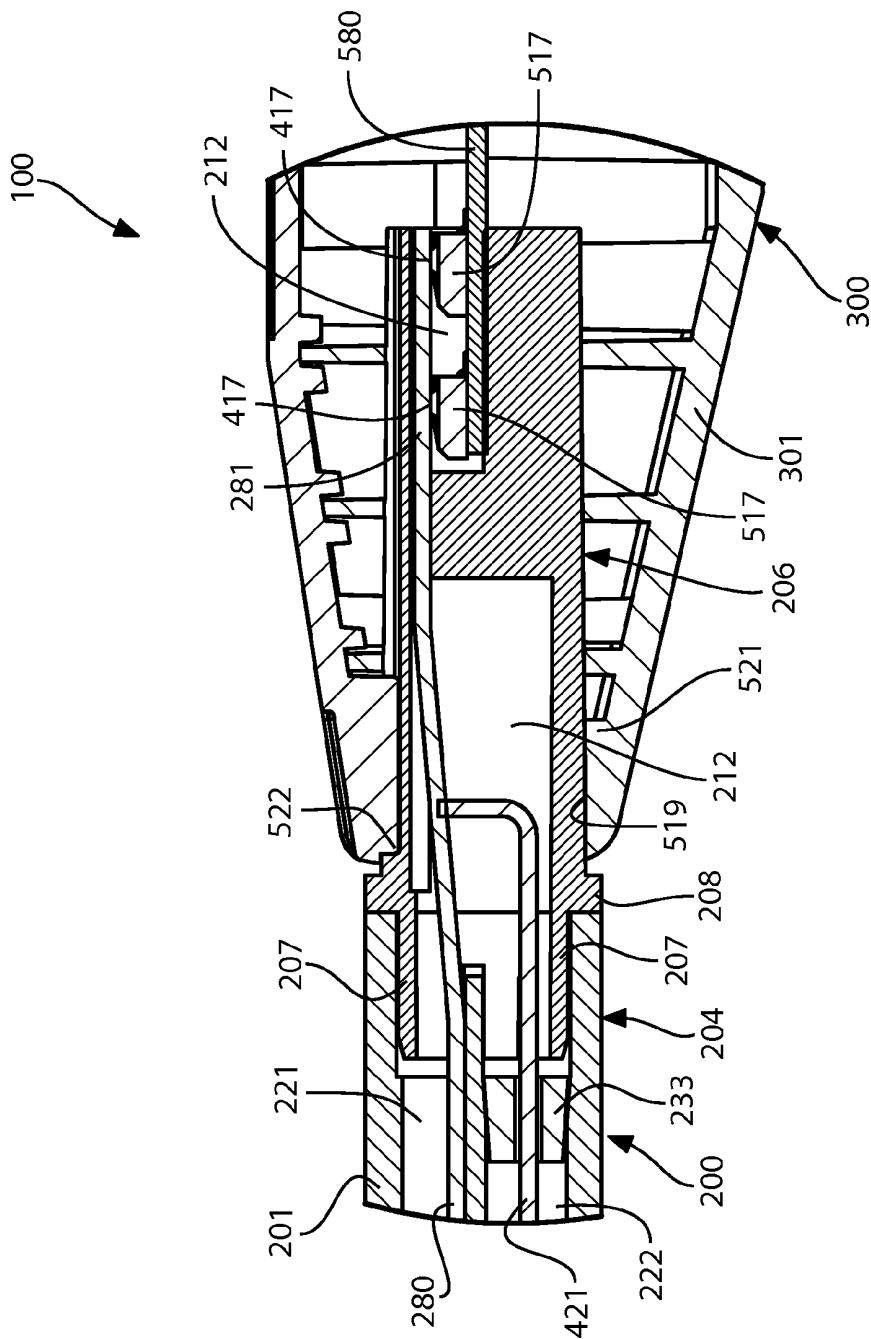


FIG. 11

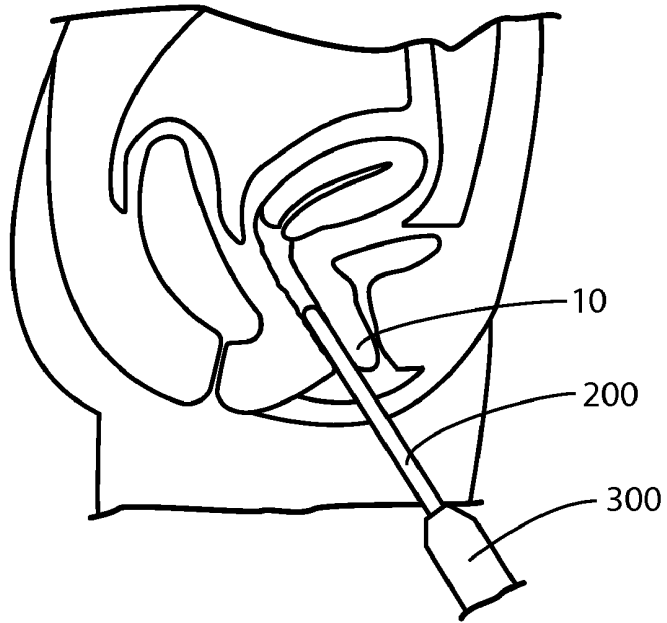


FIG. 13A

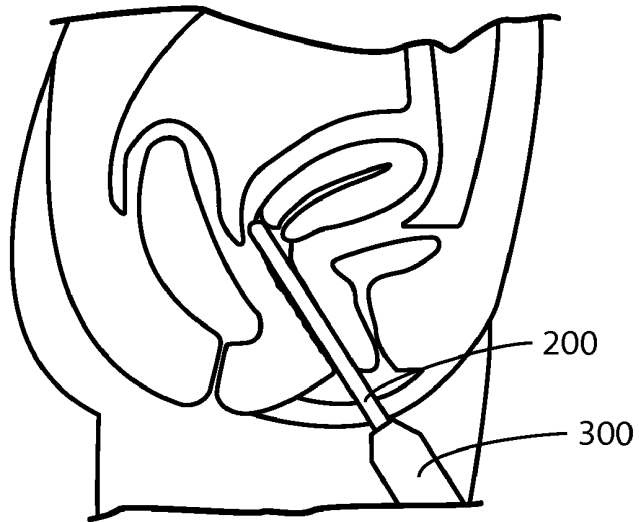


FIG. 13B

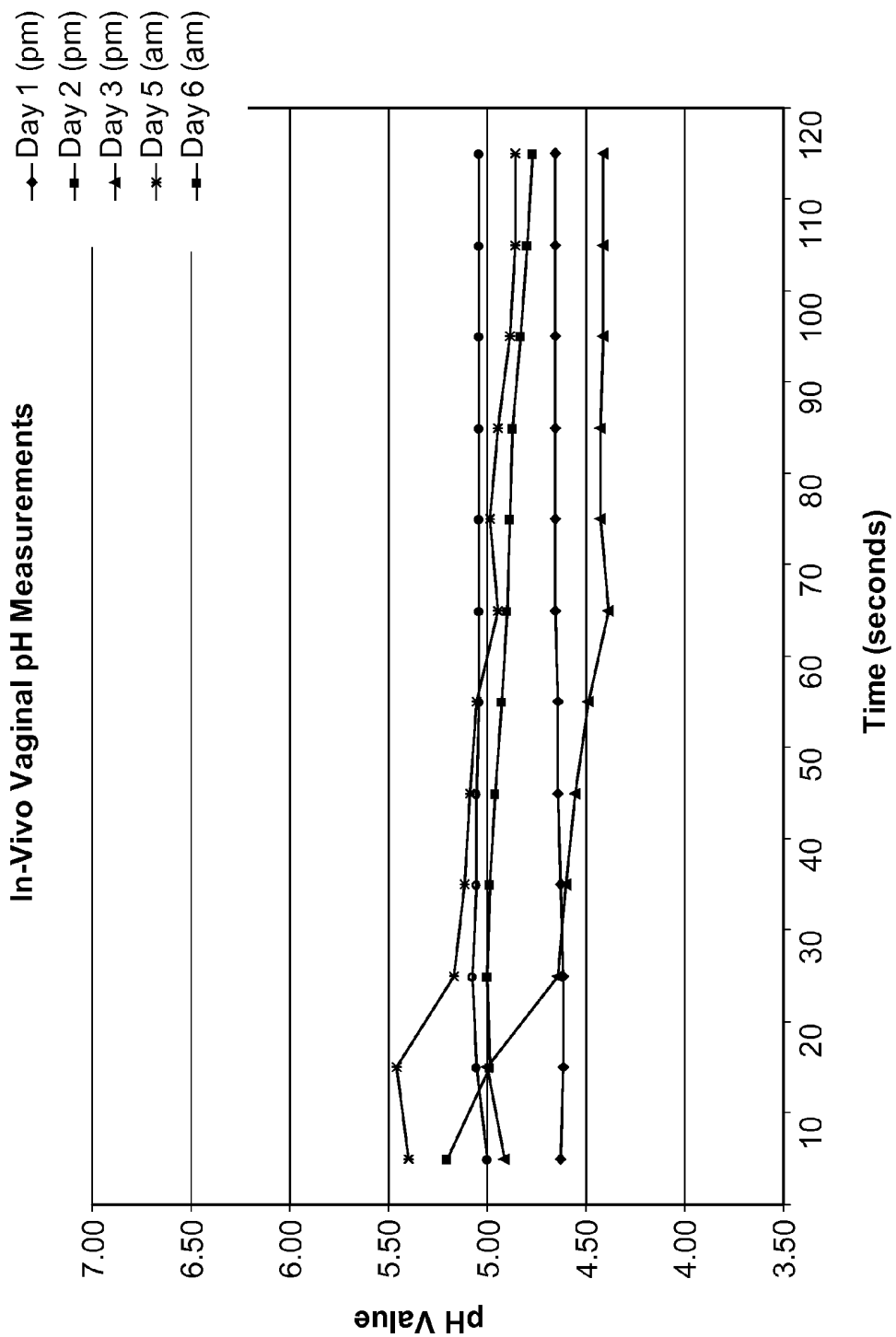


FIG. 14

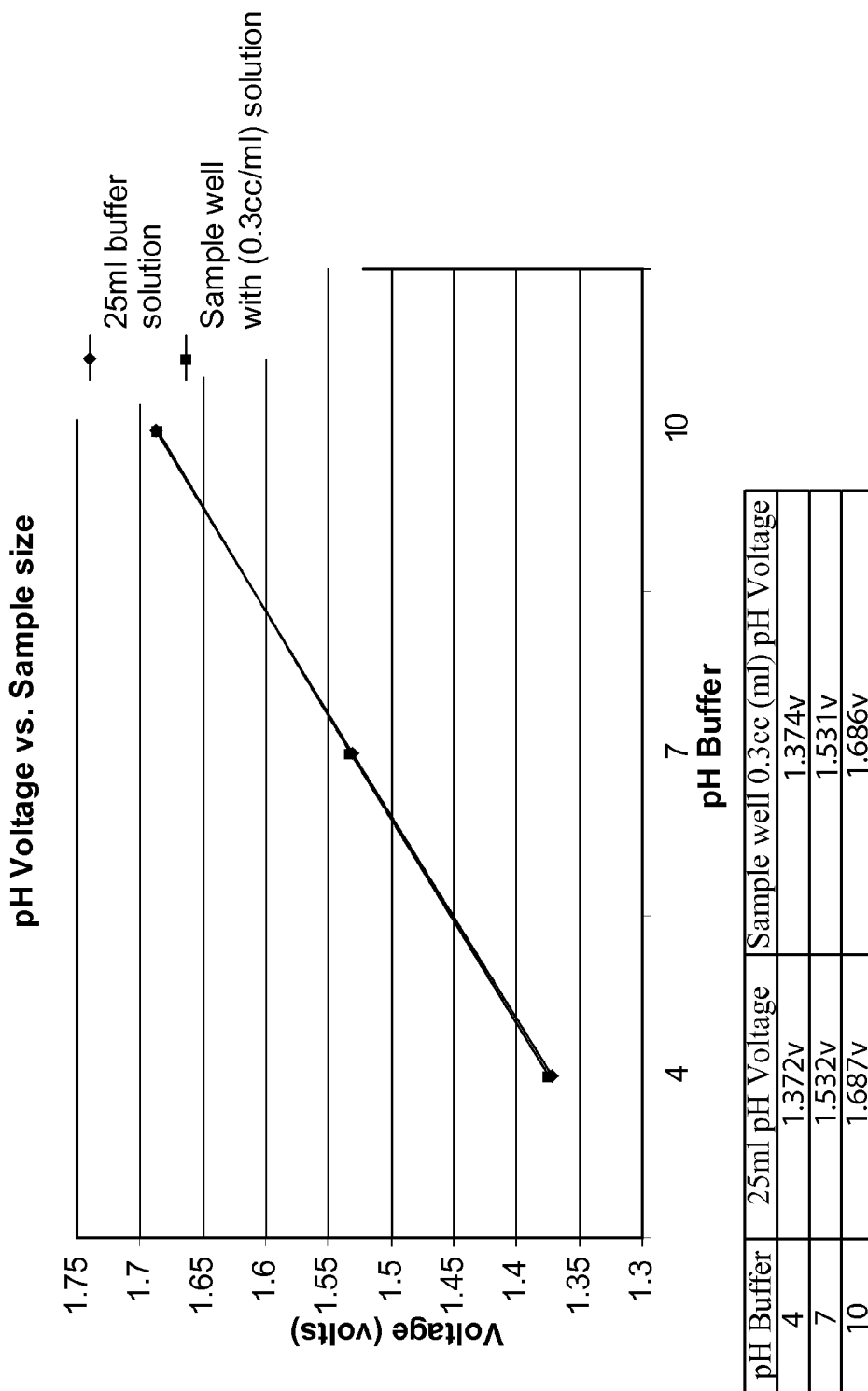


FIG. 15

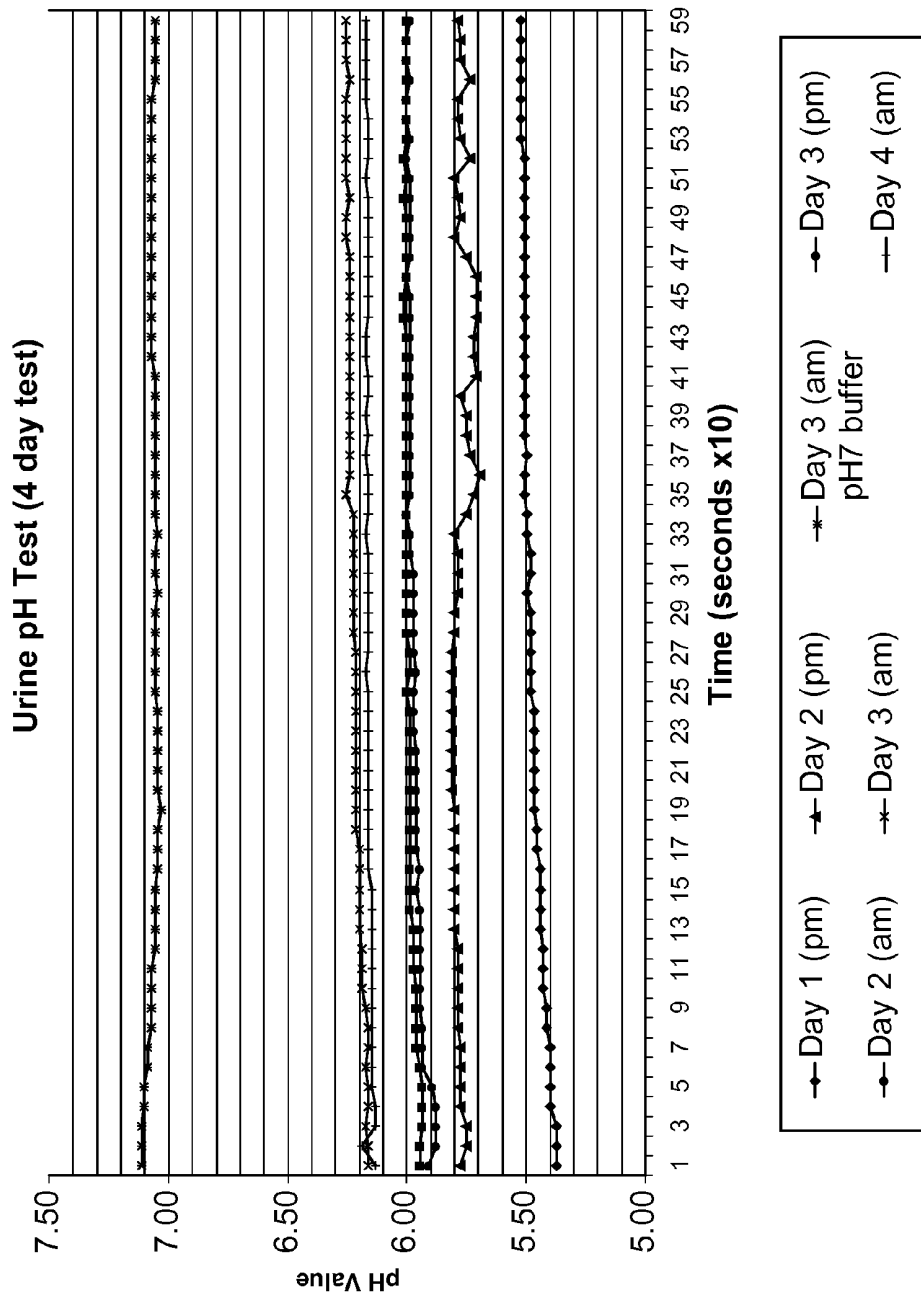


FIG. 16

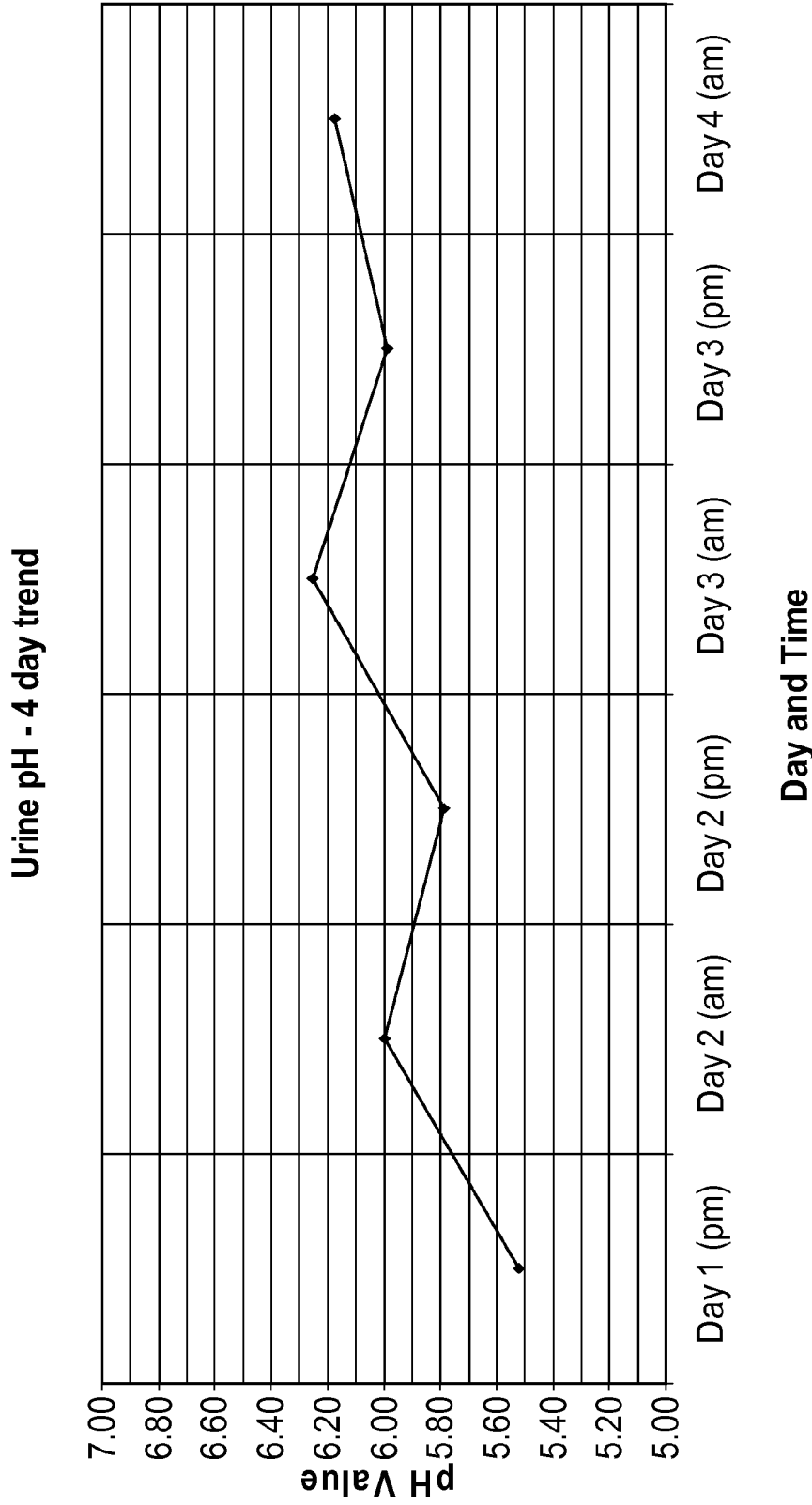


FIG. 17

**APPARATUS, METHOD AND SYSTEM FOR
DETERMINING A PHYSIOLOGICAL
CONDITION WITHIN A MAMMAL**

**CROSS-REFERENCE TO RELATED PATENT
APPLICATIONS**

[0001] The present application claims the benefit of U.S. Provisional Patent Applications Ser. No. 61/086,403, filed Aug. 5, 2008 and Ser. No. 61/231,076, filed Aug. 4, 2009, the entireties of which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to the field of determining a physiological condition within a mammal, and specifically to apparatus, methods and systems of determining a physiological condition within a mammal based on pH measurements of biological fluids taken either in vivo or externally, such as ovulation, vaginal, and/or cervical health, and other physiological conditions.

[0003] The device is particularly suited for insertion into the vagina but allows for easy pH measurement of small samples of various other bodily fluids (urine, saliva, blood) external of the body. The device shown is designed for female end user self testing but can also be a valuable aid in physicians offices and clinical labs. The invention can be used for various mammals, including human and veterinary applications.

BACKGROUND OF THE INVENTION

[0004] pH is a measure of the acidity or alkalinity of a solution or substance. Solutions with a pH less than seven are considered acidic, while those with a pH greater than seven are considered basic or alkaline. A pH level of 7.0 is considered neutral. When a pH level is 7.0, it is defined as 'neutral' because at this pH the concentration of H_3O^+ equals the concentration of OH^- in pure water. The pH value is a measure of the activity of hydrogen ions in the solution. The pH scale is typically between 1 and 14 with 1 being the most acidic and 14 the most alkaline. The pH scale is an inverse logarithmic representation of hydrogen proton concentration. Therefore a value change of 1 pH unit represents a factor of 10 increase or decrease.

[0005] The vagina is the muscular canal extending from the vaginal opening to the cervix and consists of three layers of tissue. The mucosa is the surface layer and consists of mucus membranes. The next layer of tissue is a layer of muscle concentrated mostly around the outer third of the vagina. The third layer is the innermost layer and consists of fibrous tissue.

[0006] The vagina contains folds or wrinkles rather than a smooth surface. It is usually about 3 to 5 inches in length and its walls are lined with a mucus membrane. The vagina includes numerous tiny glands that generate vaginal secretions/fluids. The vaginal walls are continually producing secretions/fluids necessary to provide lubrication, to cleanse the vagina and to maintain the proper acidity to prevent infection. The vagina tends to be fairly acidic usually in the range of 3.5 to 4.5 pH. The walls of the vagina are normally in contact with each other, which is contrary to most anatomical illustrations. When something enters the vagina its walls separate to make room for the object. Because of its muscular tissue, the vagina has the ability to expand and contract adjusting to fit snugly around the object inserted.

[0007] Accurate monitoring of vaginal pH is an important part of in the diagnosis of vaginal infections such as Bacterial Vaginosis (BV). The normal vaginal pH in reproductive age women is usually 3.5 to 4.5. A value greater than 4.5 can indicate a variety of vaginal infections which are usually accompanied by unusual discharge, itching, burning and irritation. The three diseases most frequently associated with vaginal discharge are BV, trichomoniasis (caused by a sexually transmitted infectious parasite) and candidiasis (usually caused by *Candida albicans*).

[0008] Bacterial vaginosis (BV) is the most common cause of vaginal infections. BV is caused by an imbalance of naturally occurring bacterial flora. To control bacterial growth, the vagina is normally slightly acidic with a pH of 3.5-4.5. A pH greater than 4.5 is considered alkaline and is suggestive of bacterial vaginosis.

[0009] Candidiasis, also known as a "yeast infection" or VVC, is a common fungal infection that occurs when there is overgrowth of the fungus called *Candida*. *Candida* is always present in the body in small amount, however when an imbalance occurs, such as when the normal acidity of the vagina changes or when hormonal balance changes, *Candida* can multiply. When that happens, symptoms of candidiasis appear.

[0010] Trichomoniasis, sometimes referred to as "trich," is a common cause of vaginitis. Trichomoniasis is primarily an infection of the urogenital tract with the most common site of infection the vagina or urethra in women. With a trichomonas infection, the vagina is likely to be more alkaline than normal. An estimated five million cases of trichomoniasis occur each year in the United States. Men also can contract trichomoniasis however do not often have signs or symptoms. Some men may temporarily have an irritation inside the penis, mild discharge, or slight burning after urination or ejaculation.

[0011] According to the Centers for Disease Control (CDC), there are some serious risks from BV such as;

[0012] An increase in a woman's susceptibility to HIV infection if she is exposed to HIV virus.

[0013] An increase in the chances that an HIV-infected woman can pass HIV to her sex partner.

[0014] An increase in a woman's susceptibility to further STDs such as herpes simplex virus (HSV) Chlamydia and gonorrhea.

[0015] An increase in the development of an infection following surgical procedures such as a hysterectomy or an abortion.

[0016] During pregnancy, an increase in adverse pregnancy outcomes has been detected, including premature rupture of the membranes, preterm labor, preterm birth, intraamniotic infection, and postpartum endometritis.

[0017] The results of several investigations indicate that treatment of pregnant women with BV who are at high risk for preterm delivery (i.e. those who previously delivered a premature infant) might reduce the risk for prematurity. Monitoring of pH level during pregnancy is an important criterion in reducing the incidences of Preterm labor and birth. Studies have shown that bacterial vaginosis was associated with the preterm delivery of low-birth-weight infants independently of other recognized risk factors. Reduction in the instances of premature birth improves the health of the newborn and significantly reduces the cost of care.

[0018] Oral clindamycin prevents spontaneous preterm birth and mid trimester miscarriage in pregnant women with bacterial vaginosis. Based on estimates from the CDC, the

number of pregnant women in the United States alone that are annually infected with BV is 1,080,000 and Trichomoniasis is 124,000.

[0019] Untreated bacterial vaginosis is a risk factor for post abortion pelvic inflammatory disease (PID). Studies have shown that preabortal screening and subsequent treatment of those who test clinically positive does lower the incidence of postabortion PID.

[0020] BV can be diagnosed by the use of clinical criteria or Gram stain. In clinical practice BV is diagnosed using the Amsel criteria. Clinical criteria require typically three of the following symptoms or signs:

[0021] homogeneous, thin, white discharge that smoothly coats the vaginal walls;

[0022] presence of clue cells on microscopic examination;

[0023] pH of vaginal fluid >4.5; and

[0024] a fishy odor of vaginal discharge before or after addition of 10% KOH (i.e., the whiff test).

[0025] Current methods of monitoring vaginal pH include various methods of checking pH paper type products. The accuracy of these products are generally in the range of 0.3 pH to 0.5 pH. They generally require the user to subjectively compare color in order to determine the pH value and are subject to inaccuracies. Inaccuracies can be due to lighting conditions or the ability of the user to accurately compare color. Manual recording of the subjective readings is required.

[0026] The cervix is the lower portion of the uterus and forms the neck of the uterus. The cervix joins with the top end of the vagina and the uterine cavity. The cervix protrudes into the vagina and this area is called the ectocervix. Typically the ectocervix is about 2.5 to 3 cm in diameter and has an elliptical surface. The ectocervix is also called the external os. The size and shape of the external os can vary widely depending on the age of the woman or if she has given vaginal birth. The passage way between the external os and the uterus is referred to as the endocervical canal. The endocervical canal terminates at the internal os which is the opening of the cervix inside the uterine cavity. The cervical canal of the uterus is covered by a thin layer of mucus. Pockets within the lining of the cervix function to produce cervical fluid.

[0027] Studies by George I. Gorodeski et al, such as those disclosed in U.S. Patent Application U.S./2008/0071190 published Mar. 20, 2008, show that cervical pH changes dramatically during the ovulation cycle while the vaginal pH remains relatively constant. The in-vivo vaginal and cervical pH values recorded were measured in Gorodeski by attaching a strip of pHDrion paper at the tip of uterine forceps. In addition, another more complicated clinical lab test was performed by measuring cell cultures of the human Ecto-cervical Epithelial cells and human Endocervical cells. These tissue samples were collected and then analyzed and measured using an elaborate clinical procedure. Using these techniques, it was shown that the pH of the ectocervix changes as much as 2 pH during the ovulation cycle with the peak occurring during days 11-14 of the cycle (ovulation period). During the same periods the vaginal readings remained relatively constant.

[0028] Studies have also shown that monitoring of vaginal pH can be a good indicator of menopause in women who are without vaginitis and are not receiving estrogen therapy. A pH reading greater than 4.5 could indicate menopause and the need for estrogen therapy. Low levels of estrogen can cause elevated pH levels in the area of 6.0 or higher. The sensitivity,

of FSH blood work was no different than vaginal pH in the diagnosis of menopause. Estrogen causes deposition of glycogen in mature epithelial cells, which is then converted by bacterial enzymes to glucose. The glucose is anaerobically fermented to lactic acid, which gives the vagina a pH of 3.5 to 4.5.

[0029] Further studies have shown that an important function of the vaginal and cervical epithelial cells is to regulate the pH of the lumen of the lower genital tract. During premenopausal years vaginal luminal pH ranges between 4.5 and 6.0 with mild alkalization to about 6.5 before ovulation. Lack of estrogen, such as after menopause, is associated with alkalization to about 6.5-7.0, whereas replacement with estrogen can acidify the luminal vaginal pH to about 5.5.

[0030] On a related note, there are times when urine pH can indicate serious health issues. For example, a very high (alkaline) urine pH could be caused by kidney failure or a urinary tract infection. A very low (acidic) urine pH could be the result of lung disease, complications of diabetes, starvation or diarrhea. The glomerular filtrate of blood is usually acidified by the kidneys from a pH of approximately 7.4 to a pH of about 6 in the urine. Depending on the person's acid-base status, the pH of urine may range from 4.5 to 8. The kidneys maintain normal acid-base balance primarily through the reabsorption of sodium and the tubular secretion of hydrogen and ammonium ions. Urine becomes increasingly acidic as the amount of sodium and excess acid retained by the body increases. Alkaline urine usually containing bicarbonate-carbonic acid buffer, is normally excreted when there is an excess of base or alkali in the body. Secretion of acidic or alkaline urine by the kidneys is one of the most important mechanisms the body uses to maintain a constant body pH.

[0031] A highly acidic urine pH occurs in:

[0032] Acidosis

[0033] Uncontrolled diabetes

[0034] Diarrhea

[0035] Starvation and dehydration

[0036] Respiratory diseases in which carbon dioxide retention occurs and acidosis develops

[0037] A highly alkaline urine occurs in:

[0038] Urinary tract obstruction

[0039] Pyloric obstruction

[0040] Salicylate intoxication

[0041] Renal tubular acidosis

[0042] Chronic renal failure

[0043] Respiratory diseases that involve hyperventilation (blowing off carbon dioxide and the development of alkalosis)

[0044] Urine pH is often used to monitor a person's diet. In people who are not vegetarians the pH of urine tends to be acidic. A diet rich in citrus fruits, legumes, and vegetables raises the pH and produces urine that is more alkaline. Generally an accurate measurement of urinary pH can be done only on a freshly voided specimen. If urine pH is to be useful, it is necessary to use pH information in comparison with other diagnostic information.

SUMMARY OF THE INVENTION

[0045] It is therefore an object of the present invention to provide an apparatus, system and method for determining one or more physiological conditions within a mammal based on pH measurements, including without limitation one or more of the physiological conditions discussed above.

[0046] Another object of the present invention is to provide an apparatus, system and method for measuring pH and temperature of biological fluid.

[0047] Yet another object of the present invention is to provide an apparatus, system and method for determining a physiological condition within a mammal based on either in vivo or external measurements of biological fluids.

[0048] Still another object of the present invention is to provide an apparatus, system and method for determining a physiological condition within a mammal that requires minimal calibration.

[0049] A further object of the present invention is to provide an apparatus, system and method for determining a physiological condition within a mammal that utilizes a replaceable "plug-and-play type" of probe.

[0050] A yet further object of the present invention is to provide an apparatus system and method for determining a physiological condition within a mammal that utilizes a dark environment for calibration.

[0051] A still further object of the present invention is to provide an apparatus, system and method for determining a physiological condition within a mammal that utilizes an ion-sensitive field effect transistor (ISFET) for measuring pH.

[0052] An even further object of the present invention is to provide an apparatus, system and method for determining a physiological condition within a mammal wherein the processing and logic circuitry is maintained in a handle and a minimal amount of circuitry is maintained in a replaceable probe.

[0053] Another object of the present invention is to provide an apparatus, system and method for determining the fertility status of a female mammal.

[0054] Yet another object of the present invention is to provide an apparatus, system and method for predicting ovulation in a female mammal based on current and stored pH and/or temperature measurements.

[0055] These and other objects are met by the present invention which, in one aspect, is an apparatus for measuring a physiological condition within a mammal comprising: an elongated probe for insertion into a body lumen of the mammal, the probe comprising a first circuit board operably coupling a pH sensor for measuring the pH within the body lumen and generating a pH signal indicative of the measured pH, a memory device storing parametric data unique to the pH sensor, and a first interface connector located at a proximal portion of the probe; a handle for manipulating the probe, the handle comprising a second circuit board operably coupling a microprocessor for processing the pH signal and generating an output signal based on the processing of the pH signal, a display device for displaying the output signal generated by the microprocessor, and a second interface connector; the probe connected to the handle in manner that allows the probe and handle to be repetitively engaged and disengaged from each other; and wherein when the probe is connected to the handle, the first and second interface connectors are in electrical connection so that the microprocessor can retrieve the parametric data from the memory device of the probe and receive the pH signal.

[0056] In another aspect, the invention can be an apparatus for measuring a physiological condition within a mammal comprising: an elongated probe for insertion into a body lumen of the mammal, the probe comprising a first circuit board operably coupling an ion-sensitive field effect transis-

tor (ISFET) for measuring pH within the body lumen and generating a pH signal indicative of the measured pH, a temperature sensor for measuring temperature within the body lumen and generating a temperature signal indicative of the measured temperature, a diaphragm in contact with an electrolyte solution buffered at a known pH, a memory device storing ISFET slope data at both ambient temperature and normal body temperature for the ISFET, and a first interface connector located at a proximal portion of the probe; a handle for manipulating the probe, the handle comprising a second circuit board operably coupling a microprocessor for receiving the pH and temperature signals and generating an output signal based on the processing of the pH and temperature signals and the ISFET slope data, a display device for displaying the output signal generated by the microprocessor, and a second interface connector; the probe connected to the handle in manner that allows the probe and handle to be repetitively engaged and disengaged from each other; and wherein when the probe is connected to the handle, the first and second interface connectors are in electrical connection so that the microprocessor can retrieve the ISFET slope data from the memory device of the probe and receive the pH and temperature signals.

[0057] In yet another aspect the invention can be an apparatus for measuring a physiological condition within a mammal comprising: a probe for insertion into a body lumen of the mammal, the probe comprising: an elongated tubular housing extending along a longitudinal axis from a proximal end to a distal end, the elongated tubular housing having a first internal cavity; a first circuit board located within the first internal cavity; a pH sensor for measuring pH within the body lumen located at a distal portion of the elongated tubular housing, the pH sensor generating a pH signal indicative of the measured pH and operably coupled to the first circuit board; a temperature sensor for measuring temperature within the body lumen located at the distal portion, the temperature sensor generating a temperature signal indicative of the measured temperature and operably coupled to the first circuit board; a first memory device storing parametric data unique to the pH sensor, the memory device housed within the internal cavity of the elongated tubular housing and operably coupled to the first circuit board; and a first interface connector located at a proximal portion of the elongated tubular housing and operably coupled to the circuit board; a handle for manipulating the probe, the handle comprising: a second housing having a second internal cavity and a socket forming a passageway into the second internal cavity; a second circuit board located within the second internal cavity; a microprocessor located within the second housing and operably coupled to the second circuit board for receiving and processing the pH signal and the temperature signal, the microprocessor generating an output signal based on the processing of the pH signal and the temperature signal and the parametric data; a power source located within the second housing and operably coupled to the second circuit board; user controls located on the second housing and operably coupled to the second circuit board; a display device operably coupled to the second circuit board for displaying the output signal generated by the microprocessor; a second interface connector operably coupled to the circuit board and aligned with the socket; and wherein the probe is removably secured to the handle, the proximal portion of the elongated tubular housing extending into the socket of the second housing so that the first and second connectors are in electrical connection.

[0058] In still another aspect, the invention can be an apparatus for measuring a physiological condition within a mammal comprising: an elongated tubular housing extending along a longitudinal axis from a distal end to a proximal end, the housing having an internal cavity; a first opening in the elongated housing forming a first passageway into the internal cavity; an ISFET for measuring pH within a body lumen of the mammal, the ISFET positioned in the internal cavity, the ISFET aligned with the first opening so that at least a portion of the ISFET is exposed via the first opening; and a first seal between the ISFET and the housing forming a hermetic seal about a perimeter of the first opening.

[0059] In a further aspect, the invention can be an apparatus for measuring a physiological condition within a mammal comprising: an elongated tubular housing extending along a longitudinal axis from a distal end to a proximal end; and an ISFET for measuring pH within a body lumen of the mammal, the ISFET located on a distal portion of the housing and having at least a portion of the ISFET exposed for contact with fluid of the body lumen.

[0060] In a yet further aspect, the invention can be an apparatus for measuring a physiological condition within a mammal comprising: an elongated tubular housing extending along a longitudinal axis from a distal end to a proximal end; an ion-sensitive field effect transistor (ISFET) for measuring pH within a body lumen of the mammal, the ISFET located on a distal portion of the housing and having at least a portion of the ISFET exposed; a temperature sensor for measuring temperature within the body lumen, the temperature sensor located on a distal portion of the housing and having at least a portion of the temperature sensor exposed; a memory device storing parametric data unique to the pH sensor the parametric data includes first ISFET slope data determined at ambient temperature and second ISFET slope data determined at normal body temperature; a first interface connector operably coupled to the ISFET, the temperature sensor and the memory device, the first interface connector located at the proximal end of the housing; and a first circuit board located within the housing, the ISFET, the temperature sensor, the memory device and the first interface connector operably coupled to the first circuit board.

[0061] In a still further aspect, the invention can be an apparatus for measuring a physiological condition within a mammal comprising an elongated housing extending along a longitudinal axis from a proximal end to a distal end, the housing having an internal cavity; a transverse wall extending along the longitudinal axis that separates the internal cavity into a first chamber and a second chamber, the first and second chamber isolated from one another and extending in an axial adjacent manner along the ion longitudinal axis; a par-cylindrical cutout in the elongated housing forming an open end of the first chamber and exposing a portion of the transverse wall; a pH sensor for measuring pH within a body lumen of the mammal and a temperature sensor for measuring temperature within the body lumen, the pH sensor and the temperature sensor located on the exposed portion of the transverse wall; a par-cylindrical cover having a well for collecting biological fluids, the well having an annular wall and a floor, and first and second openings forming first and second passageways through the floor of the well respectively; and the par-cylindrical cover secured to the elongated housing so that the pH sensor is exposed via the first opening and the temperature sensor is exposed via the second opening, the par-

cylindrical cover covering the par-cylindrical cutout so as to hermetically seal the open end of the first chamber.

[0062] In an even further aspect, the invention can be an apparatus for measuring a physiological condition within a mammal comprising: an elongated housing extending along a longitudinal axis from a proximal end to a distal end, the housing having an internal cavity; a transverse wall separating the internal cavity into a first chamber and a second chamber; a cutout in the elongated housing forming an opening into the first chamber and exposing a portion of the transverse wall; a pH sensor for measuring pH within a body lumen of the mammal and a temperature sensor for measuring temperature within the body lumen, the pH sensor and the temperature sensor located on the exposed portion of the transverse wall, a cover having a well for collecting biological fluids, first and second openings forming first and second passageways through a floor of the well; and the cover secured to the elongated housing so that the pH sensor is exposed via the first opening and the temperature sensor is exposed via the second opening, the cover covering the cutout so as to hermetically seal the opening into the first chamber.

[0063] The invention may also, in one aspect, be an apparatus for measuring a physiological condition within a mammal comprising: an elongated housing extending along a longitudinal axis from a proximal end to a distal end, the housing having an internal cavity; a wall within the internal cavity; a cutout in the elongated housing forming an opening into the internal cavity and exposing at least a portion of the transverse wall, a pH sensor for measuring pH within a body lumen of the mammal and located on the exposed portion of the transverse wall; a cover having a first opening forming a first passageway through the cover; and the cover secured to the elongated housing so that the pH sensor is exposed via the first opening, the cover covering the cutout so as to hermetically seal the opening into the internal cavity.

[0064] In another aspect, the invention can be a system for measuring a physiological condition within a mammal comprising: an apparatus comprising: an elongated housing extending along a longitudinal axis from a proximal end to a distal end; a pH sensor for measuring pH within a body lumen of the mammal, the pH sensor located at a distal portion of the elongated housing; a temperature sensor for measuring temperature within the body lumen, the temperature sensor located at the distal portion of the elongated housing; and a handle having a second housing for manipulating the elongated housing, the second housing having a top surface, a bottom surface and a plurality of lateral surfaces bounding the top and bottom surfaces, the elongated housings protruding from one of the lateral surfaces of the second housing; a removable cap for enclosing the distal portion of the elongated housing, the cap comprising: a base having a first channel in a top surface of the base, a lid having a second channel in a bottom surface of the lid; and wherein when the removable cap is in a closed position, the lid is positioned atop the base so that the bottom surface of the lid opposes the top surface of the base and the first and second channels form a cavity having an open end and a closed end; and wherein when the removable cap is secured to the elongated housing in the closed position, the distal portion of the elongate housing nests within the cavity and a remaining portion of the elongated housing protrudes from the open end of the cavity.

[0065] In yet another aspect, the invention can be a system for measuring a physiological condition within a mammal comprising: an apparatus comprising: an elongated housing

extending along a longitudinal axis; a pH sensor for measuring pH within a body lumen of the mammal, the pH sensor located at a distal portion of the elongated housing; and a second housing for manipulating the elongated housing, the elongated housing protruding from the second housings, a removable cap for enclosing the distal portion of the elongate housing, the cap comprising: a base having a first channel in a top surface of the base, a lid having a second channel in a bottom surface of the lid; and wherein the lid is pivotably mounted to the base so as to be pivotable between: (i) an open position wherein the distal portion of the elongated housing can be laid into the first channel by movement in a direction substantially perpendicular to the longitudinal axis; and (ii) a closed position wherein the first and second channels form a heretically sealed cavity about the distal portion of the elongated housing.

[0066] The invention can, in even another aspect, be a system for measuring a physiological condition within a mammal comprising: an apparatus comprising: an elongated housing extending along a longitudinal axis, a pH sensor for measuring pH within a body lumen of the mammal, the pH sensor located at a distal portion of the elongated housing; and a removable cap for enclosing the distal portion of the elongate housing, the cap comprising: a base having a first channel in a top surface of the base; a lid having a second channel in a bottom surface of the lid; and wherein the lid is pivotably mounted to the base so as to be pivotable between: (i) an open position wherein the distal portion of the elongated housing can be laid into the first channel by movement in a direction substantially perpendicular to the longitudinal axis; and (ii) a closed position wherein the first and second channels form a heretically sealed cavity about the distal portion of the elongated housing.

[0067] In still another aspect, the invention can be a method of determining fertility and/or vaginal health status in a female mammal comprising: inserting a probe into a vagina of the female mammal, a distal portion of the probe comprising an ISFET for measuring pH and temperature sensor for measuring temperature, the probe comprising a memory device storing parametric data unique to the pH sensor; measuring pH and temperature with the ISFET and the temperature sensor of the probe; transmitting signals indicative of the measured pH and temperature to a microprocessor; the microprocessor generating an output signal indicative of the fertility and/or vaginal health status in the female mammal based on the signals indicative of the measured pH and temperature and the parametric data; and displaying the output signal on a display device of the probe.

[0068] In a further aspect, the invention can be a method of determining fertility and/or vaginal health status in a female mammal comprising: inserting a probe into a vagina of the, a distal portion of the probe comprising a pH sensor for measuring pH and a temperature sensor for measuring temperature, the probe comprising a first memory device storing parametric data unique to the pH sensor; measuring pH and temperature with the pH sensor and the temperature sensor of the probe; transmitting signals indicative of the measured pH and temperature to a logic controller; the logic controller generating an output signal indicative of the fertility and/or vaginal health status in the female mammal based on the signals indicative of the measured pH and temperature and the parametric data; and communicating the output signal to a user.

[0069] In an even further aspect, the invention can be a method of determining fertility and/or vaginal health status in a female mammal comprising: inserting a probe into a vagina of the female mammal, a distal portion of the probe comprising an ISFET for measuring pH and a temperature sensor for measuring temperature; measuring pH and temperature with the ISFET and the temperature sensor of the probe; transmitting signals indicative of the measured pH and temperature to a microprocessor; the microprocessor generating an output signal indicative of the fertility and/or vaginal health status in the female mammal based on the signals indicative of the measured pH and temperature; and communicating the output signal to a user.

[0070] The invention may, in yet another aspect, be a method of determining fertility and/or vaginal health status in a female mammal comprising: providing an apparatus comprising: an elongated probe housing a first circuit board operably coupling a pH sensor, a temperature sensor, and a first interface connector located at a proximal portion of the probe; and a handle for manipulating the elongate probe the handle housing a second circuit board operably coupling a microprocessor, an indicia device, and a second interface connector; connecting the elongated probe to the handle so that the first and second interface connectors are in electrical connection; inserting the elongated probe into a vagina of the female mammal; measuring pH and temperature with the pH sensor and the temperature sensor of the probe; transmitting signals indicative of the measured pH and temperature to the microprocessor; the microprocessor generating an output signal indicative of the fertility and/or vaginal health status in the female mammal based on the signals indicative of the measured pH and temperature and the parametric data; and communicating the output signal to a user via the indicia device.

[0071] In still another aspect, the invention can be a method of calibrating an apparatus for taking in vivo pH measurements comprising: a) providing a probe having an elongated housing extending along a longitudinal axis, a well formed in a top edge of the elongate housing for holding fluids, a pH sensor located on a floor of the well, the well located at a distal portion of the elongated housing; b) positioning the distal portion of the elongated housing on a base of a removable cap, the removable cap having a lid in an open position; c) supplying a liquid buffered to a known pH to the well and in contact with the pH sensor; d) moving the lid of the removable cap to a closed position so that the distal portion of the elongated housing is enclosed in a cavity of the removable cap, the cavity being substantially free of visible light; and e) calibrating the pH sensor to the known pH.

BRIEF DESCRIPTION OF THE DRAWINGS

[0072] FIG. 1 is an isometric view of a vaginal health apparatus according to an embodiment of the present invention wherein the probe has been disassembled from the handle.

[0073] FIG. 2 is a high level electrical schematic for the probe of the vaginal health apparatus of FIG. 1.

[0074] FIG. 3 is high level electrical schematic for the handle of the vaginal health apparatus of FIG. 1.

[0075] FIG. 4 is a top view of the probe of the vaginal health apparatus of FIG. 1.

[0076] FIG. 5 is a cross-sectional view of the probe of FIG. 4 taken along view V-V.

[0077] FIG. 6 is an exploded view of the probe of FIG. 4.

[0078] FIG. 7 is a close-up top view of the distal portion of the probe of FIG. 4.

[0079] FIG. 8 is a cross-sectional view of the distal portion of the probe taken along view VIII-VIII of FIG. 7.

[0080] FIG. 9 is a top view of the vaginal health apparatus of FIG. 1 in an assembled state.

[0081] FIG. 10 is a cross-sectional view of the vaginal health apparatus along view X-X of FIG. 9.

[0082] FIG. 11 is a close-up view of area XI of FIG. 10.

[0083] FIG. 12A is a perspective view of a removable cap according to one embodiment of the present invention, the removable cap being in an open position.

[0084] FIG. 12B is a perspective view of a vaginal health system according to one embodiment of the present invention including the vaginal health apparatus of FIG. 1 and the removable cap of FIG. 12A.

[0085] FIG. 13A is a schematic of the vaginal health apparatus of FIG. 1 inserted into the vagina of a human female and positioned for vaginal pH and temperature measurements.

[0086] FIG. 13B is a schematic of the vaginal health apparatus of FIG. 1 inserted into the vagina of a human female and positioned for cervical pH and temperature measurements.

[0087] FIG. 14 is a graph of in vivo pH measurement versus time for a human female subject over a six day period wherein readings were taken every ten seconds over a two minute period.

[0088] FIG. 15 is a data chart and corresponding graph of pH measurements versus voltage of three different pH buffers based on sample size so that effects of the well size on pH readings could be evaluated.

[0089] FIG. 16 is a graph of measured pH versus time for urine over a four day period wherein the urine was externally measured in the sample well.

[0090] FIG. 17 is a four day trend line graph of the final urine pH measurements of FIG. 16.

DETAILED DESCRIPTION OF THE INVENTION

[0091] One or more embodiments of the present invention will be discussed in this section with reference to FIGS. 1-17. The embodiments illustrated herein are not intended to be exclusive or to limit the invention to the precise form or application disclosed. The embodiments are chosen and described merely to explain one or more desired embodiments of the structure, use and/or application of the invention. While the invention is specifically described below as a vaginal health device, the invention is not limited to this application or to the exact structure exemplified. The present invention can be used to determine any physiological condition of a mammal that can be determined by pH and/or temperature values and/or variations thereof over a period of time. The invention can be used to determine any physiological condition, such as fertility, vaginal health, oral health, gastro-intestinal health, dietary health, etc. Specific examples of physiological conditions within the scope of this invention include without limitation ovulation, menopause, acidosis, diabetes, diarrhea, starvation and dehydration, respiratory disease, urinary tract obstruction, pyloric obstruction, salicylate intoxication, renal tubular acidosis, chronic renal failure, BV, candidiasis and trichomoniasis. Moreover, the present invention can be used to measure the pH and/or temperature of biological fluids both externally and in vivo. For external measurements, the sample well allows for the accurate measurement of pH and/or temperature for bodily fluids such as saliva, urine, and blood. For in vivo measurements, the invention can also take pH and/or temperature measurements in any desired

body lumen, including without limitation the vagina, cervix, esophagus, mouth, nasal passages, auditory canals, digestive tract, urethra, and vascular system.

[0092] The invention is generally described in relation to the human female. However, the inventive principals can be applied in veterinary applications with a simple modification of the size (length and diameter) and/or shape of the structure to fit various mammals including dogs, cats, dairy cows and horses. As a result, veterinary applications for monitoring vaginal pH, cervical pH, oral pH or urinary pH can be accomplished for diagnosis and determination of a physiological condition in the art of veterinary medicine.

[0093] The invention allows for measurement of the pH and/or temperature of biological fluids in a private (i.e., in the home) or clinical lab environment. As will be discussed in detail below, the invention allows for easy change, updating and/or replacing of the probe of the apparatus to keep up with latest technologies in measuring pH. For example, in some embodiments of the invention, the pH sensor may be a reference FET (REFET) which could be implemented with an ISFET and a pseudo reference electrode. In such a design, the electrode wire (which is typically an Ag/AgCl coated wire) and electrolyte solution may be eliminated.

[0094] Additionally, the incorporation of the vital product data (VPD) into a memory device within the probe of the apparatus allows the probe to be easily interchanged with other logic assemblies without the need for extensive two point calibration. The incorporation of the VPD information within the probe itself simplifies user operation as key information about the probe characteristics and use are stored within the memory device of the probe itself. The logic assembly (which acts as the handle) can easily read this information in order to guide the user through proper operation, whether it is taking measurements or calibration. The ability to store and retrieve important calibration and other information within the probe make the invention a "plug-and-play" type of device.

[0095] Referring now to FIGS. 1 and 9, a vaginal health apparatus 100 is illustrated according to one embodiment of the present invention. The vaginal health apparatus 100 generally comprises a probe component 200 (sometimes referred to as the "probe") and a handle component (sometimes referred to as the "handle"). The vaginal health apparatus 100 is illustrated in FIG. 1 in a disassembled state wherein the probe 200 has been disconnected from the handle 300. In FIG. 9, the vaginal health apparatus 100 is illustrated in an assembled state wherein the probe 200 is connected to the handle 300.

[0096] The general structure and shape of the probe 200 is formed by its elongated housing 201, which in the illustrated embodiment, has an elongated linear rod-like shape. The elongated housing 201 extends from a proximal end 202 to a distal end 203 along a longitudinal axis A-A (FIG. 4). The elongated housing 201 is a tubular structure that is specifically sized and shaped for insertion into the human vagina so that pH and/or temperature measurements can be taken either in the vaginal tract or at the cervix. Of course, other elongated shapes can be utilized, including curved rods.

[0097] The elongated housing 201 has a substantially circular transverse cross-sectional profile. Of course, the elongated tubular housing 201 can have a transverse cross-sectional profile of various shapes and sizes. The exact size and shape of the elongated housing 201 will be dictated by the end use to which the vaginal health apparatus 100 is to be put, and

is not to be considered limiting of the present invention unless specifically recited in the claims.

[0098] Conceptually, the elongated housing 201 comprises a proximal portion 210, a middle portion 220 and a distal portion 230. A fluid sample well 240 is formed in the distal portion 230 of the probe 200. The well 240 acts as a reservoir for holding biological fluids, such as urine, saliva, blood, cervical fluids, vaginal fluids and/or other bodily fluids. A pH sensor 250, a temperature sensor 260 and a diaphragm 270 are located within the well 240.

[0099] Turning to the handle, the general structure and shape of the handle 300 is formed by its box-like housing 301, which in the illustrated embodiment, comprises a tapered portion 310 and a generally rectangular box portion 320. The handle housing 301 provides a means by which the user can manipulate the movement of the probe 200 within the desired body lumen (when assembled as discussed below). The handle housing 301 comprises a top surface 302, a bottom surface 303, and a plurality of lateral surfaces 304 that bound the top and bottom surfaces 302, 303, thereby forming a substantially closed and hollow structure. The handle 300 generally comprises a display device 330, user controls 340-342, a first data port 314 and a second data port 315 (these elements will be discussed in greater detail below).

[0100] When the vaginal health apparatus 100 is assembled (as shown in FIG. 9), the probe 200 is removably (i.e., non-fixedly) secured to the handle 300. In other words, the probe 200 and the handle 300 are connected in a manner that allows the probe 200 and the handle 300 to be repetitively connected and disconnected without compromising the structural or functional integrity of either the probe 200 or the handle 300. In the illustrated embodiment, the probe 200 is removably secured to the handle 300 by slidably inserting the proximal portion 210 of the elongate housing 201 into a socket 519 (visible in FIG. 11) formed into the tapered portion 310 of the handle housing 301. The socket 519 of the handle housing 301 and the proximal portion 210 of the elongated housing 201 are correspondingly sized and shaped (relative to one another) so that a tight fit exists between the proximal portion 210 of the elongate housing 201 and the walls of the socket 519 of the handle housing 301 when the proximal portion 210 is fully inserted within the socket 519. This tight fit assembly provides adequate structural connectivity between the handle 300 and the probe 200 so that the probe 200 does not separate (or otherwise become dislodged) from the handle 300 during use. The proximal portion 210 of the elongated housing 201 has a tapered transverse cross-sectional area that helps facilitate slidable insertion into the socket 519 of the handle housing 301 and increases frictional engagement with the walls 521 (FIG. 11) of the socket 519.

[0101] While the non-fixed connection between the probe 200 and the handle 300 is exemplified as a tight-fit assembly, other mechanisms and structural arrangements can be implemented to effectuate the desired connection, either in addition to or in replace of the tight-fit technique. For example, one or more depressions could be provided in either the proximal portion 210 of elongated housing 201 or the walls 521 of the socket 519 of the handle housing 301 that snap-fit (or otherwise mate) with tangs (or some other protuberance) provided on the other one of the proximal portion 210 of elongated housing 201 or the walls 521 of the socket 519 of the handle housing 301. Alternatively, the outer surface of the proximal portion 210 of the elongate housing 201 and the walls 521 of the socket 519 of the handle housing 301 can be provided with

corresponding threads for threaded engagement. In other embodiments a bayonet lock, magnets, cotter pins, or combinations of the aforementioned techniques could be implemented.

[0102] A slot 211 is formed into the proximal portion 210 of the elongate housing 210 of the probe 200. The slot 211 is a linear slot that extends from the proximal end 202 toward the distal end 203 of the elongated housing 201 along a top edge of the elongated housing 201. The slot 211 is provided on the elongated housing 201 to ensure proper rotational orientation of the elongated housing 201 when the probe 200 is connected to the handle 300. A key or other protuberance 522 (FIG. 11) is provided on the wall 521 of the socket 519 of the handle housing 301. When the probe 200 is in the proper rotational orientation during assembly, the key 522 mates with the slot 211, allowing the proximal portion 210 to enter the socket. However, if the probe 200 is in an improper rotational orientation during assembly, the key 522 prohibits the proximal portion 210 from entering the socket. An indicia marker 311 on the top surface 302 of the handle housing 301 indicates the circumferential position of the key 522 (or protuberance) within the socket 519. The key/slot assembly also prevents undesired rotation of the probe 200 with respect to the handle 300 once assembly of the vaginal health apparatus 100 is achieved. As will be discussed below, proper rotational orientation of the probe 200 with respect to the handle 300 during and after assembly is important to ensure proper and stable electrical connection between the separate circuit boards of the probe 200 and the handle 300.

[0103] The probe 200 can be removed from the handle 300 for easy cleaning with warm water or mild soapy water and then rinsed with warm water. In a clinical environment the probe 200 would need to be sterilized with something similar to CIDEX OPA solution (Johnson and Johnson). Alternately, the probe 200 could be designed with material such as PEEK and be subjected to autoclaving temperatures of about 130° C. For the illustrated embodiment, the use of non-autoclaving process is suggested. The probe 200 in this embodiment is approximately 0.04 inches in diameter and 7 inches long. Changes in dimensions can be accommodated in order to support pH measurement in other female mammals.

[0104] As will be discussed immediately below, the circuitry to be positioned within the probe 200 and the circuitry to be positioned within the handle 300 is strategically selected so that: (1) the probe 200 is as inexpensive as possible so that it can be discarded and replaced as necessary; (2) the handle 300 can be used in conjunction with different probes 200 and still provide accurate and reliable measurements; (3) all data relating to the measurements taken over periods of time is stored within the handle 300 for either internal or external processing; and/or (4) the need for calibration is minimized. As a result of this strategic separation and placement of circuitry, the handle 300 becomes the logic controller assembly of the vaginal health apparatus 100.

[0105] Referring to FIGS. 2-3 concurrently, the strategic separation and selection of the circuitry necessary to run the vaginal health apparatus 100 is shown according to one embodiment of the present invention. FIG. 2 is a high level electrical schematic of the circuit 400 which is located within the elongated housing 201 of the probe 200. FIG. 3 is a high level electrical schematic of the circuit 500 which is located within the housing 301 of the handle 300.

[0106] With reference to FIG. 2, the primary components of the circuit located within the probe 200 are the pH sensor 250,

an analog interface circuit **416**, a reference electrode **421**, the temperature sensor **260**, the diaphragm **270**, KCL solution **422**, a non-volatile, memory **415** and an interface connector **417**. All of these components are operably coupled via a circuit board, which is located within the elongated housing **201**, as is well known in the art.

[**0107**] The pH sensor **250** is preferably an ISFET which is a semiconductor device which has the metal gate replaced with a hydrogen-ion sensitive layer. The ISFET **250** is the primary element in measuring the hydrogen ion concentration (i.e. the pH) of the biological fluid to be measured with the vaginal health apparatus **100**. When the hydrogen ions contact the gate sensitive layer of the ISFET **250**, the voltage between the gate and source of the ISFET is influenced. The reference electrode **421** is required to close the electrical circuit loop. The analog circuitry **416** drives the electrode **421** in order to maintain a constant current through the drain and source of the ISFET **250**. It is this drive voltage change that is used as the pH output signal and used by the A/D converter **502** (which located on the circuit **500** within the handle **300**) to measure pH of the biological fluid under examination. The reference electrode **421** is preferably a typical Ag/AgCl coated wire and is placed in the KCL solution **422**. The diaphragm **270** is the conduit between the KCL solution **422** and the biological fluid being measured. While the pH sensor is preferably an ISFET, in some embodiments of the invention the pH sensor can be a combination of ISFET and REFET (Reference FET) with a Pseudo Reference Electrode. As technology improves for the creation of the REFET it would be easy to replace the combination of the ISFET and standard Reference Electrode comprised of the reference electrode **421** and KCL solution **422**. For example the ISFET and REFET could be produced on the same substrate with a platinum electrode which may consist simple of an evaporated layer of Pt deposited on the ISFET/REFET substrate. It is also possible for a totally solid-state sensing probe to be incorporated into the invention.

[**0108**] The temperature sensor is preferably a thermistor, and more preferably, a typical NTC (negative temperature coefficient) device. While the temperature sensor is preferably a thermistor, in some embodiments of the invention the temperature sensor can be a thermocouple or infrared detector.

[**0109**] The non-volatile memory **415** is preferably a simple wire serial memory that can be read by and written to by the microprocessor **510** (which is located on the circuit **500** of the handle **200**). The interface connector **417** is preferably one or more PCB pads. The invention, however, it so limited and any suitable mechanism technique or device that can be used to repetitively engage and disengage with a corresponding interface connector to operably and electrically couple circuits together can be used. For example, the interface connector **417** could be multi-pin connector, a USB connector, a firewire connector, or other jack or pin and socket combination.

[**0110**] Referring now to FIG. 3, the primary components of the circuit **500** located within the handle **300** are the microprocessor **510**, A/D converter **502**, the display device **330**, control switches **340-342**, the first and second data ports **314, 315**, an interface connector **517** a DC/DC converter **515**, an audible device **516**, and a battery **520**. All of these components are operably coupled via a circuit board, which is located within the handle housing **301**, as is well known in the art.

[**0111**] The control switches **340-342** are used to select various functions of the vaginal health apparatus **100**, such as

power on/off calibration, start/stop measurements etc. These functions can be displayed via menu screens on the display device **330**. The display device **330** is preferably an LCD display panel such as a full graphic display or a simple segmented and icon based display. However, the display device **330** can be any type of device used to visibly display information or status, such as one or more LEDs, OLED display, or other types of screens, such as plasma or LED.

[**0112**] The first and second data ports **314, 315** can be any type of wired or wireless port that can facilitate data transfer and communication between the vaginal health apparatus **100** and an external electronic device, such as a computer, cell phone, handheld data assistant, or the like. Examples of data ports include without limitation firewire ports, USB ports, mini USB ports, IRDA ports, serial ports (such as RS232) multi-pin ports, RF transceivers, etc.

[**0113**] The interface connector **517** is preferably one or more compression connectors for operably and electrically coupling with the interface connector **417** of the circuit **400** of the probe **200**. As discussed above, the interface connector **517** is selected to mate with the type of interface connector **416** chosen for the probe **200**. Any of the types of connectors mentioned above for the interface connector **417** can be used for the interface connector **517** of the circuit **500** of the handle **300**.

[**0114**] The interface connectors **417, 517** are selected and positioned within the probe **200** and handle **300** respectively so that when the probe **200** is assembled/connected to the handle **300** (as described above) the interface connectors **417, 517** come into and stay in operable connection with one another so that data signals and power can be transmitted between the two circuits **400, 500**. When the interface connectors **417, 517** are in operable connection the power source **520**, which is preferably in the form of a lithium coin cell battery, provides the necessary power for both of the circuits **400, 500**. Additionally, pH and temperature signals generated by the pH and temperature sensors **250, 260** are transmitted to the microprocessor **510** (after passing through the A/D converter **502**) for processing and or storage. Additionally, the microprocessor **510** can access and retrieve data (such as parametric data, such as properties and parametric data, that is inherent to the pH sensor **250**), stored in the memory device **415** of the circuit **400**.

[**0115**] Referring now to FIGS. 4-6 concurrently, additional details of the probe **200** will be discussed. As discussed above, the probe **200** comprises an elongated housing **201** which extends from a proximal end **202** to a distal end **203** along the longitudinal axis A-A. The elongated housing **201** comprises a main housing portion **204**, a cover **205** and a coupling **206**. Preferably, the elongated housing **201** is constructed of a plastic, such as a medical grade ABS material, or other biocompatible material.

[**0116**] The coupling **206** forms the proximal portion **210** of the elongated housing **201** while the cap **205** extends along the distal portion **230** of the elongated housing **201**. The coupling **206** comprises four spaced apart flexible tabs **207** extending from its distal edge for insertion into the internal chamber(s) **221, 222** of the main housing portion **204**. When the probe **200** is assembled, the flexible tabs **207** of the coupling **206** are slid into the internal chamber(s) **221, 222** of the main housing portion **204** until a collar **208** of the coupling **206** contacts the proximal edge of the main housing portion **204**. Frictional contact between the tabs **207** and the inner surface of the main body portion **204** secure the coupling **206**

to the main body portion 204. The connection between the coupling 206 and the main body portion 204 can be further enhanced by using an adhesive, sonic weld, thermal weld, or any other connection techniques that are now known or later developed in the art. Preferably, the interface between the coupling 206 and the main housing portion 204 is hermetic so that fluids can not enter the elongate housing 201 at this location.

[0117] The lower longitudinal section 209 of the coupling 206 is solid while the upper longitudinal section comprises a cavity 212 that extends the entire length of the coupling 206, thereby forming a longitudinal passageway through the coupling 206. The cavity 212 is in spatial communication with the slot 211 (which was discussed above in detail). When the coupling 206 is secured to the main body portion 204 when the probe 200 is assembled, the cavity 212 of the coupling is in spatial communication with the top chamber 221 of the main body portion 204. As explained in greater detail below, this allows the circuit board 280 (the majority of which is housed in the upper chamber 221 of the main housing portion 204) to extend into the cavity 212 of the coupling 206.

[0118] As discussed above, the transverse cross-sectional profile of the coupling 206 is tapered along its longitudinal length, with the smallest area being at the proximal end 202. This allows the coupling 206 to be inserted into the socket 519 of the handle housing 300.

[0119] The main housing portion 204 comprises an outer tubular wall 213 that forms an elongated internal cavity. A transverse wall 214 that extends along the longitudinal axis A-A is provided within (and integrally formed with) the outer tubular wall 213, thereby separating the elongated internal cavity into a first longitudinal chamber 221 and a second longitudinal chamber 222. The first and second longitudinal chambers 221, 222 extend in an axial adjacent manner and are hermetically isolated from one another. The transverse wall 214 is preferably centrally arranged within the other tubular wall 213 but can be offset from the longitudinal axis if desired. The transverse wall 214 is preferably a flat wall having planar upper and lower surfaces. The invention, however, is not so limited and the transverse wall can take on other shapes and contours if desired.

[0120] A par-cylindrical cutout 215 is provided at the distal portion 230 of the main housing portion 204, thereby exposing a portion 216 of the wall 214 and creating an open end for the upper chamber 221. While the "missing portion" of the main housing portion 204 is described as a "cutout," it is not necessary for the opening to be the result of some type of cutting, punching or breaking process. It is intended that the term "cutout" merely mean an opening which, for example, may result from the main housing portion 204 being formed in the illustrated shape during an injection molding process. Additionally, the exact shape and location of the cutout 215 can vary as desired.

[0121] A plurality of protuberances 217 (in the form of pins) project upward from the upper surface 232 of the exposed portion 216 of the transverse wall 214. The protuberances 217 are provided to mate with corresponding bores in the cap 205 to ensure proper alignment between the cap 205 and the main housing portion 204 during assembly of the probe 200. A retaining structure 218, in the form of a upstanding U-shaped wall, also projects upward from the upper surface 232 of the exposed portion 216 of the transverse wall 214. The retaining structure 218 and some of the protuber-

ances 217 retain and align the circuit board 280 in its proper position within the upper chamber 221 when the probe 200 is assembled.

[0122] A hole/opening 219 is provided on the exposed portion 216 of the transverse wall 214 that forms a passageway through the transverse wall into the lower chamber 222 of the elongated housing 201. The holes is 219 is sized and shaped to accommodate the diaphragm 270 so that a first portion of the diaphragm 270 is exposed to the biological fluid being tested while a second portion of the diaphragm 270 protrudes into the lower chamber 222 and is in contact with the KCL solution 422.

[0123] The cover 205 is a par-cylindrical structure that is sized and shaped to correspond to the cutout 215 so that the cover 205 can enclose the cutout 215 when the probe 200 is assembled. The connection of the cover 205 to the main housing portion 204 will be described below in greater detail with reference to FIGS. 7-8. The cover 205 generally comprises an outer surface 225. The well 240 is formed into the outer surface 225 of the cover 205.

[0124] The cover 205 comprises three holes/openings 226-228 (which are located on a floor 241 of the well 240) that provide passageways through the cover 205. The opening 226 is sized and shaped to accommodate the diaphragm 270 so that it is exposed to biological fluids during use via the opening 226. The opening 227 is sized and shaped to accommodate the pH sensor-ISFET 250 so that it is exposed to biological fluids during use via the opening 227. The opening 228 is sized and shaped to accommodate the temperature sensor 260 so that it is exposed to biological fluids during use via the opening 228. The walls 229 of the opening 227 are tapered to help funnel and direct the biological fluids into contact with the ISFET 250. The walls 231 of the opening 228 are also tapered to help funnel and direct the biological fluids into contact with the temperature sensor 260.

[0125] The ISFET 250, the temperature sensor 260, the non-volatile memory chip 415, the reference electrode 421 and the interface connector 416 are all mounted on the small printed circuit board 280. The ISFET 250 is typically mounted to the printed circuit board 280 via epoxy and wire bonds although other mounting techniques, such as compression connections, are possible. As will be discussed in greater detail below, only a portion of the ISFET 250 contains the hydrogen ion sensing portion which makes contact with the test liquid or material via the opening 227.

[0126] The non-volatile memory chip 415, which is also located on the printed circuit board 280, is utilized to store various data. Generally, the data stored in this memory 415 is referred to herein as Vital Product Data (VPD). The VPD information contains information such as probe serial number, probe manufacturer, calibration information, parametric data unique to the ISFET and temperature sensor being used, and time since last calibration. The VPD information is intended to be used by the microprocessing unit 510 in the handle housing 300. The processing unit 510 will always read the contents of the memory device 415 to identify the VPD information in order to determine what if any actions might be required by the user before measurement.

[0127] For example, in one embodiment of the invention, the VPD information stored in the memory device 415 of the probe 200 includes:

[0128] 1) Serial # information (fields 00-09). This contains important information regarding build date and location.

- [0129] 2) Vendor Name (fields 10-24)
- [0130] 3) Assembly # (fields 25-2E)
- [0131] 4) 3 point calibration information at ambient (room temperature) (fields 30-37 in VPD_details)
- [0132] 5) 3 point calibration information at body temperature (98.6F. or 37C.). (fields 38-3F in VPD_details)
- [0133] 6) Date Last Calibrated (fields 60-65 in VPD_details)
- [0134] 7) Number of Measurements Since Last Calibration (fields 66-67 in VPD_details)
- [0135] 8) Number of pH measurements Taken (fields 68-6A in VPD_details)
- [0136] 9) ISFET Leakage (fields 46-47)
- [0137] 10) ISFET Lot # (fields 48-4F)

[0138] Storing the "Date Last Calibrated" in the memory device 415 allows the microprocessor 510 to force the user to follow proper operation procedures in order to maximize accurate measurements. For example if it is determined that the vaginal health apparatus 100 has not been calibrated for an extended period of time, say 30 days, the firmware would not allow the user to take a vaginal measurement until pH7 buffer calibration in the sample well 240 is completed.

[0139] Storing the "Number of Measurements Since Last Calibration" in the memory device 415 ensures proper calibration in the event that, even if the vaginal health apparatus 100 was calibrated within a specific time frame, but was used say 10 times without calibration, the microprocessor 510 would then force the user to calibrate to maintain accuracy. For example in a doctor's office or other clinical environment, if they used it 10 times in one day the microprocessor 510 would force the doctor to do a calibration procedure to make sure accurate measurements are taken.

[0140] Storing the "Number of pH Measurements Taken" in the memory device 415 ensures that the useful end of life of the product can be monitored. For example if it is determined that drift occurs within the vaginal health apparatus 100 (say the KCL electrolyte solution ages or gets slightly contaminated) after 2000 measurements, the vaginal health apparatus 100 can automatically notify the user that the probe 200 needs to be replaced with a new one.

[0141] By storing calibration information at room and ambient temperature in the memory device 415, more accurate pH measurements can be attained by utilizing the unique temperature characteristics of the ISFET 250. The temperature correction factor can be obtained by calculating differences in slope or absolute values. For example if the readings at 98.6° F. vary by 0.1 pH versus the readings at ambient (say 70° F.) then the microprocessor 510 can compensate for these readings when vaginal measurements are taken. So, if a user does an occasional pH7 buffer calibration in the sample well 240, the microprocessor 510 would be able to determine the 'correction factor' for a measurement at 98.6°F. Correction for tolerances associated with the thermistor 260 and series resistor can be automatically compensated for as the absolute value at 98.6° F. is stored during the manufacturing test and calibration process.

[0142] Storing the VPD information in the memory device 415 within the probe 200 allows for "plug and play" operation by the end user, thereby simplifying operation and making this a user friendly product. The storage of the VPD information in the memory device 415 within the probe 200 is also important to minimize the number and level of calibration cycles required. Inclusion of parametric data that is unique to the specific ISFET 250 and the thermistor 260 being used is

an important factor in reducing and simplifying the amount of required user interaction and calibration. For example, the processing unit 510 may read the field indicating that the probe was not calibrated for an extended period of time and would automatically force the user to run a single point calibration to insure proper measurement results.

[0143] As set forth and exemplified above, the VPD information contains parametric data unique to the characteristics of the particular ISFET and thermistor housed within that probe assembly. The ability to store this unique parametric data enables the firmware within the handle housing 300 to read specific data which enables more accurate measurements and simplifies user operation. The ISFET is a semiconductor device similar to a MOSFET. As such it has characteristic curves for current and voltage. The desired mode of operation for the ISFET is in a constant drain to source voltage (V_{ds}) and constant drain to source current (I_{ds}). As the characteristics curves of the ISFET change slightly from ISFET to ISFET, the absolute voltage values will change as well when implemented in the circuit. ISFETs are built on silicon wafers and thus the parametric properties of each ISFET will vary from lot to lot and, in some instances, even vary from wafer to wafer or device to device (even if on the same wafer). Such differences are due to tolerances and inherent variations in the manufacturing process. These differences result in slight variables in ISFET characteristic such as ISFET leakage current, drain-source voltage/current curves, capacitance, etc. As stated earlier, the gate portion of the ISFET is replaced with an ion sensitive layer which can consist of material such as Si_3N_4 , Al_2O_3 . Variations in the ion sensitive layer will also contribute to the characteristics of the ISFET. The combination of these ISFET characteristics along with temperature determines the slope and absolute voltage for a given pH. Thus, one ISFET placed in the circuit may exhibit a slope voltage per pH characteristic of say 55 mv/pH while another ISFET may produce a slope characteristic of 54 mv/pH. In addition, the absolute voltage value generated by the circuitry for a particular ISFET placed in a fixed buffer solution will vary among ISFETs. It is these variances and others that effect the parametrics of the ISFET/probe combination that require and are stored in the VPD within the probe assembly.

[0144] All of these unique characteristics add up to make each and every ISFET 250 slightly unique, even when from the same wafer. Thus, when the ISFET 250 is put into the circuit 400 in the factory, the slope of each ISFET 250 and the absolute voltage value for a particular pH value will be different.

[0145] Also how the ISFET 250 drifts with time due to leakage current will be different since the leakage current of each device will be unique to the case of ISFETs, variables also exist regarding the gate membrane material application which will certainly have an effect as well. Each ISFET will also have unique characteristics regarding drift with temperature. So, by storing the parametric data that is unique to the exact ISFET 250 being used in the completed probe 200, the vaginal health apparatus 100 can compensate for as many variables as possible that effect the readings. Because the probe 200 also includes other electronics, such as the op amp, the voltage reference, the Ag/AgCL electrode and electrolyte solution (which complete the ISFET circuit), the ISFET 250 is essentially profiled along with all the other components that complete the probe 200.

[0146] The following are examples of parametric data unique to the ISFET 250 (and the assembled combination of electrode 421, KCL electrolyte 422 solution and diaphragm 270) that are stored in the memory device 415.

ISFET xpH Factory Value Low Temp:

[0147] This is the value measured and programmed during final production test. These values are used to determine the ISFET slope. These values are only programmed at the factory during final testing. They will however be read by the software within the handle 300 to determine ISFET slope. The value programmed in this field should reflect the ambient temperature (25C.).

Low Temperature Value:

[0148] This is the temperature value measured during the ISFET Factory Low Temperature value calibration cycle. It is written the same time as the ISFET xpH Factory Value Low Temp fields are written. This temperature should be approximately 25C.

ISFET xpH Factory Value High Temp:

[0149] This is the value measured and programmed during final production test. These values are used to determine the ISFET slope. These values are only programmed at the factory during final testing. They will however be read by the software within the handle 300 to determine ISFET slope. The value programmed in this field should reflect the high temperature value of 39C. +/-0.1C. (98.6F. +/-0.2F.).

High Temperature Value:

[0150] This is the temperature value measured during the ISFET xpH Factory High Temperature value calibration cycle. It is written the same time as the ISFET xpH Factory Value High Temp fields are written. This temperature should be 39C. +/-0.1C. (98.6F. +/-0.2F.).

ISFET Temp Correction Value:

[0151] This is a place holder for any information that might be required for correction of pH Value with temperature. It is assumed that the ISFET xpH Factory Value will be calculated and programmed while at 25° C. The Correction Value should be for measurement at 37° C. or if correction is linear the correction required per 1° C.

ISFET Leakage Current:

[0152] This is a value in stored in uA so that it can be used to possible determine ISFET drift over time and used by software to possible compensate for this.

[0153] Referring still to FIGS. 4-6 the circuit board 280 is of an elongated shape and is positioned within the upper chamber 221. More specifically, the circuit board 280 is positioned within the upper chamber 280 and secured to the upper surface 232 of the transverse wall 214. The circuit board 280 is held in place against the transverse wall 214 via keying system in order to make sure that the ISFET 250 and temperature sensor 260 are properly aligned with the openings 227, 228 of the cover 205 when the cover 205 is secured to the main housing portion 204 to enclose (and seal) the cutout 205.

[0154] A proximal portion 281 of the circuit board 280 extends into the cavity 212 of the coupling 206. The proximal portion 281 of the circuit board 280 comprises the interface

connector 417, in the form of PCB pads, which are located on the bottom surface of the circuit board 280 for operable contact/mating with the interface connector 517 of the handle housing 300 when the vaginal health apparatus 100 is assembled.

[0155] While the circuit board 280 is located within the upper chamber 221, the reference electrode 421 extends from the circuit board 280 and into the lower chamber 222. The lower chamber 222 is filled with an electrolyte solution 422 that is buffered at a known pH, such as KCL at a pH of 7.0. The lower chamber 222 is hermetically sealed in order to prevent any leakage of the electrolyte solution 422. The sealing of the open end of the lower chamber 222 is accomplished using an electrolyte plug 233. The reference electrode 421 extends through a small hole 234 in the plug 233. The appropriate hermetic seal is then formed with an appropriate epoxy or ultrasonic or thermal welding.

[0156] Referring now to FIGS. 7-8 concurrently, the construction of the distal portion 230 of the probe 200, and the relationship between its components, will be described in greater detail. As discussed above, the cover 205 of the probe 200 comprises a well 240 that acts as a reservoir for holding a biological fluid that is to be measured with the vaginal health apparatus 100. The well 240 is a depression, channel or groove formed into a top edge of the cover 205 that acts as a reservoir (or small bowl) for biological fluids. In addition the well 240 provides a method for taking in-vitro measurements. Sample material or swabs can be taken and placed into the sample well 240 if desired.

[0157] The sample well 240 also provides a method for easy calibration and a reduction of the amount of calibration solution required. Only a small volume of buffer solution (a few drops) will be required for the calibration process. Of course, the well 240 can be modified to accommodate more or less material by easily modifying the length, width or depth of the depression.

[0158] The well 240 comprises a floor 241 and an annular rim 242 that surrounds the floor 241. The annular rim 242 provides an upstanding wall that retains the biological fluid within the well 240. The well 240 is designed into the probe 200 so that it can be easily inserted into the vagina for in-vivo measurement of the vaginal wall surface or the ectocervix. During such use, the annular rim 242 can be scraped against the vaginal wall or cervix by rotating the probe 200 so as to force fluids into the well 240.

[0159] The ISFET 250, the temperature sensor 260 and the diaphragm 270 are embedded within the floor 241 of the well 240 in order to provide an accurate pH measurement. The ISFET 250, the temperature sensor 260 and the diaphragm 270 are exposed to the exterior of the apparatus 100 via the openings 226-228, which are aligned along an axis that is spaced from and substantially parallel to the longitudinal axis A-A. Aligning the openings 226-228 on such an axis ensures that the diaphragm 270, ISFET 250 and temperature sensor 260 all make contact with the sample material, allowing for an accurate pH measurement and/or temperature measurement.

[0160] The wall 229 of the opening 227 that surrounds the ISFET 250 is tapered/sloped to assist in capturing and directing the fluids and/or tissue in contact with the ISFET 250. Similarly, the wall 231 of the opening 228 that surrounds the temperature sensor 260 is also tapered/sloped to assist in capturing and directing the fluids and/or tissue in contact with the temperature sensor 260.

[0161] A fluid tight seat is required around the ISFET 250 and the temperature sensor 260 in order to prevent contamination or leakage of fluids into the electronics of the probe 200. However, both the ISFET 250 and the temperature sensor 260 need to remain exposed via the openings 227, 228 in order to take accurate pH and temperature measurements.

[0162] The hermetic seal of the opening 27 about the ISFET 250 can be accomplished by various means, such as an epoxy, O-ring or gasket seal. In the illustrated embodiment, a gasket 235 is compressed between the bottom surface of the cover 205 and the perimeter portion of the ISFET 250. The gasket 235 can be held in place by the plastic cover 205 or could be over molded onto the bottom surface of the cover 205.

[0163] The temperature sensor 260 preferably comprises a metal cap 261 that is placed over and covers a thermistor 262. The metal cap 261 can be constructed of a medical grade stainless steel or other metal which is a good thermal conductor. A small space/gap exists between the metal cap 261 and the thermistor 262. The space/gap, in one embodiment, is approximately 0.005 inches. This space/gap is filled with a material, such as an epoxy, having high thermal conductivity but that is electrically non-conductive. Filling this gap/space with such a material reduces the thermal time constant of taking a temperature measurement. In the illustrated embodiment, a surface mount thermistor is used. However, a typical bead thermistor can also be utilized and adhered to the stainless steel cap 262.

[0164] The metal cap 261 keeps the thermal time constant as low as possible and should have as small an area as practical with a thickness kept as thin as practical (0.10" in this embodiment). The temperature sensor 260 is used for measuring the temperature of the vagina or cervix during the pH measurement. Although an exemplary application of the temperature sensor 260 is detailed, those skilled in the art will appreciate that an alternate temperature sensing device can be used, such as a thermocouple or infrared detection. The temperature sensor 260 also provides temperature information used during the manufacturing process and calibration in order to allow for proper thermal compensation of the pH reading.

[0165] As with the ISFET 250, it is necessary to create a fluid tight seal about the opening 228 while leaving the metal cap 261 exposed to the biological fluid/tissue to be tested via the opening 228. The hermetic seal of the opening 228 about the metal cap 261 can be accomplished by various means, such as an epoxy, O-ring or gasket seal. In the illustrated embodiment, a gasket 236 is compressed between the bottom surface of the cover 205 and the top surface of the metal cap 261. The gasket 236 can be held in place by the cover 205 or could be over molded onto the bottom surface of the cover 205. The gasket 236 is compressed the proper amount when the plastic cover 205 is secured to the main housing portion 204.

[0166] The gaskets 235, 236 are sufficiently compressed when the plastic cover 205 is secured to the main housing portion 204. The cover 205 is permanently secured to the main housing portion 204 so that the cutout 215 is hermetically sealed, thereby sealing the distal portion of the upper chamber 221. The interface between the cover 205 and the main housing portion 204 can be sealed by epoxy, a sonic weld, a thermal weld or another compressed gasket.

[0167] The diaphragm 270 is positioned within and extends through the opening 226 of the cover 205 and the opening/

hole 219 in the transverse wall 214 of the elongate housing 201. A first portion 271 of the diaphragm 270 is exposed to the biological fluid being measured via the opening 226 while a second portion 272 of the diaphragm 270 extends into the lower chamber 222 via the hole 219. The second portion 272 of the diaphragm 270 is in contact with the KCL solution 422 within the lower chamber 222 of the elongate housing 201. The walls 237 of the opening 226 extend transversely (relative to the longitudinal axis) and contact the transverse wall 214 so as to form a seat at the interface between the two, thereby keeping the upper chamber 221 (and the circuit board 280) hermetically sealed from fluids and contamination.

[0168] The diaphragm 270 can be either a ceramic or PTFE material that is commonly used in pH probe assemblies. The diaphragm 270 allows the hydrogen ion flow between the reference electrode 421 and the KCL solution 422 and the measurement fluid. The diaphragm 270 provides the electrical connection between the reference electrode 421 and the biological fluid being measured.

[0169] Referring now to FIGS. 10-11 concurrently, the assembly of the probe 200 to the handle 300, which also operably couples the measuring circuit 400 to the logic circuit 500, will be discussed in greater detail. When the probe 200 is assembled to the handle 300, the proximal portion 210 (i.e. the coupling 206) of the probe 200 is inserted into the socket 519 of the handle housing 301 as discussed above. The assembly of the probe 200 to the handle 300 results in the operable connection of the probe circuit 400 (FIG. 2) to the logic circuit 500 (FIG. 3) because the gold plated PCB pads 417 of the printed circuit board 280 of the probe 200 come into operable and electrical connection with the compression connectors 517 of the printed circuit board 580 of the handle 300. The gold plated PCB pads 417 are configured in a manner such that the Ground signal pin, which is the return path for the supply voltage provided by the housing 300, is slightly longer (about 0.020") at the proximal 210 end than the other gold plated PCB pads. The purpose of this extended pad is so the first electrical connection made when inserting the probe 200 into the housing 300 is the ground pin. This first "make" connection helps in providing a discharge path for any erroneous charges that may be residing in the probe 200 or housing 300 assemblies. The other function of this elongated pin is to provide the last connection when disengaging the probe 200 from the housing 300 thereby keeping the ground connection in place as the last signal to disengage or "break". This type of configuration is commonly referred to as 'make before break' and helps prevent damage to the electrical components within both the probe 200 and housing 300 assemblies due to electro-static discharge or capacitive discharge when engaging and disengaging these assemblies.

[0170] Referring now to FIGS. 12A and 12B, a protective cap 600 for the distal portion 230 of the probe 200 is illustrated alone and secured to the distal portion 230 of the probe 200. The cap 600 is preferably constructed of an opaque material that is pliable. As illustrated in FIG. 12A, the cap 600 is in an open position. In FIG. 12B, the cap 600 is in the closed position and secured to the probe 200 in the intended manner.

[0171] The cap 600 generally comprises a lid 610 and a base 620. The lid 610 is pivotably connected to the base 620 via hinges 601 so as to be capable of rotation about axis B-B. A latch assembly 630, 631 is provided to lock the cap 600 in a closed position.

[0172] The lid 610 comprises a bottom surface 611 and a channel 615 formed into the bottom surface 611. The channel

615 has an open end **616** and a closed end **617**. A first rim **618** protrudes the floor **619** of the channel **615** at the open end **616**. A second rim **614** extends along the perimeter of the lid **610** and protrudes outward from the bottom surface **611**.

[0173] Similarly, the base **620** comprises a top surface **621** and a channel **625** formed into the top surface **621**. The channel **625** has an open end **626** and a closed end **627**. A first rim **628** protrudes from the floor **629** of the channel **625** at the open end **626**. The base **620** further comprises a plurality of legs **640** for supporting the base at a desired height.

[0174] When the lid **610** is rotated about axis B-B to the closed position, the bottom surface **611** of the lid **610** comes into contact with the top surface **621** of the base **620**. As a result, the two channels **615**, **625** come together to collectively form an internal cavity that is sized and shaped to accommodate the distal portion **230** of the probe **200**. This internal cavity has an open end through which the remaining length of the probe **200** can protrude (as shown in FIG. 12B). The opposite end of the internal cavity is closed.

[0175] When the cap **600** is in the closed position, the rim **614** of the lid **610** becomes compressed between the lid **610** and the top surface **621** of the base **620** so as to form a gasket seal between the lid **610** and the base **620**. Similarly, when the cap **600** is in the closed position and the cap is secured to the probe **200** (as shown in FIG. 12B), the rims **618**, **628** come together to collectively form an annular rim that acts as a gasket seal between the outer surface of the probe **200** and the floors **619**, **629** of the cap **600**. The rims **614**, **618**, **628** are made of material that has a sufficiently low durometer value so as to create the gasket type seals. The latch assembly **630**, **631** keeps these gasket seals in tact when locked. As a result, when the cap **600** is closed and secured to the probe, the distal portion **230** of the probe **200** (including the well **240**) is housed in the sealed internal cavity of the cap **600**. Moreover, because the cap is constructed of opaque material, this internal cavity is substantially free of visible light (i.e., it is dark).

[0176] The cap **600** serves multiple purposes in this particular aspect of the invention. The primary function of the cap **600** is to protect the ISFET **250** during storage. Scratching of the ISFET **250** can damage the ion sensitive membrane and effect operation. A secondary function of the cap **600** is to create a hermetically sealed internal storage cavity about the distal portion **230** of the probe **200** (which includes the ISFET **250**, temperature sensor **260** and diaphragm **270**) to keep the diaphragm **270** slightly hydrated between uses. A drop of de-mineralized or distilled water can be placed in the cap **600** once the probe **200** is laid in the channel **625** and then sealed with the latch mechanism **330**, **331**.

[0177] The third function of the cap **600** is to act as a support mechanism for the vaginal health apparatus **100** so that the sample well **240** of the probe **200** is held level and not susceptible to tipping during measurements. The legs **640** of the cap act as supports to raise the tip of the probe **200** so that the longitudinal axis A-A of the probe **200** is substantially horizontal when the distal portion **230** of the probe **200** is resting within the channel **625**. Thought of another way, because the bottom edge of the probe **200** is non-coplanar with the bottom surface **303** of the handle **300**, the probe **200** will have a tendency to tip/tilt. Thus, the height of the legs **640** is selected so that when the distal portion **230** of the probe **200** is resting within the channel **625**, the bottom surfaces of the legs **640** are substantially coplanar with the bottom surface **303** of the handle **300**.

[0178] A fourth function of the cap **600** is to provide a cover for the ISFET **250** during the sample well measurement and/or during calibration. The ISFET **250** is a semiconductor device and as such, is susceptible to UV light. Various manufacturers of ISFET's have different levels of sensitivity and generally measurement isn't affected greatly unless directly exposed to sunlight or high intensity lighting. However by placing the biological fluid to be measured in the well **240** and securing the cap **600** to the probe **200**, the measurement will always be taken in a dark environment which would reduce the potential effects of UV light impacting the reading. This "dark" environment more accurately simulates the condition within the vaginal canal and cervix or of the environment of the fluid within the body.

[0179] Referring now to FIG. 13A, the insertion of the probe **200** into the vaginal cavity is illustrated for measuring pH within the vagina. When inserted, the well **240** makes contact with the vaginal wall **10**. The vaginal walls **10** make contact with each other and separate as the probe **200** is inserted. The vaginal wall **10** is coated with mucus membrane with a muscular tissue underneath which then forms around the probe **200** and into the well **240**. The well **240** allows for the collection of the mucus fluids from the vaginal wall **10**. The well **240** of the probe **200** is typically placed in the lower portion of the vaginal canal (approximately 1 to 2 inches). Upon the user selecting the measurement function via the user controls **340-342**, the pH will be measured by the ISFET **250** and the user will be notified with at audio tone at completion of the measurement. The measured pH will be shown on the LCD screen **330** and saved within the memory device within the handle **300** (which is incorporated into the processor **510**, but may be a separate device). This stored data is stored alone with a date and time stamp so that the data can be retrieved, analyzed and compared to later measurements according to known algorithms or relationships to determine a physiological condition in a mammal, such as fertility status.

[0180] FIG. 13B shows the placement of the probe **2010** further up the vaginal cavity and making contact with the ectocervix area of the cervix. The well **240** makes contact with the ectocervix and collects cervical fluid for measurement. As stated earlier, the measurement of the cervical pH can be a useful aid in determining the fertility cycle of the female mammal. The probe **200** would typically be inserted about 4 to 5 inches in the vaginal canal in order to make contact with the cervix. The device as shown provides a simple and reliable method of measuring the cervical fluid to determine a condition, such as fertility status.

[0181] FIG. 14 is a graph of a 6 day plot of in-vivo vaginal pH measurement using the above described invention. The data was gathered from a human female approximately age 55 and in good health. The woman was post menopausal and used the device daily for a period of 6 days. Readings were sampled every 10 seconds over a 20 second period and recorded. Data was transferred from the device **100** through the RS232 serial port **314** and ported into an Excel spreadsheet. The data displayed represents the pH recorded during the test period. It shows stable readings after a short initial settling time. The final values over the 120 second measurement period were stable and within a range of 4.41 to 5.04 over the 6 day period. No special handling or calibration was performed during the 6 day usage other than simple cleaning with warm water. Periodic calibration with pH7 buffer utilizing a few drops in the sample well after extended periods of

non-use is recommended to guarantee the accuracy of measurements. If the apparatus **100** were not used for an extended period of time, the logic unit **510** would notify the user to proceed with a simple calibration procedure before taking the vaginal measurement.

[0182] An additional test was performed to compare pH buffer measurements based on sample size. FIG. **15** is a graph of the pH voltage measured from the apparatus **100** when the probe **200** was inserted into 25 ml of buffer solution and then compared against 0.3 cc/ml of solution placed into the sample well **240**. The device **100** was allowed to stabilize for 5 minutes before measurements were recorded and cleaned in water and dried between measurements. A syringe was used to insure constant amount of solution was placed into the sample well **240**. As the data shows, there is no significant difference in the measurement taken in the sample well **240** vs. the 25 ml solution. The readings are typically within 1 mv which converts to a pH variance of about 0.02 pH. The data proves that the sample well **240** is of appropriate size to accurately measure small samples of solutions. It should be noted that in this implementation of the invention about 40% of the sample well area was occupied by the thermistor and therefore it is likely that the results would be similar with <0.2 cc/ml of solution as that is all that was required to submerge the ISFET **250** and the diaphragm **270** required for the pH measurement.

[0183] As the results above for the sample size comparisons indicate, that there is no significant difference in the sample size test results. Therefore a test was performed to measure urine in the sample well. The device **100** was calibrated with pH buffer in the sample well **240** prior to the start of the test. FIG. **16** shows the results of this 4 day test. Sampling was done twice daily, once in the early morning as soon as waking and again in later afternoon prior to a meal. No calibration was done during the period however an additional test was performed on day 3 using pH7 buffer solution in place of urine. This test was done to verify the continued accuracy of the measurements since calibration was not performed between urine measurements. The data shows the device **100** was still accurate within 0.05 pH after 4 days of use w/o any daily calibration required. The probe **200** was cleaned with warm water and lightly patted dry with no special storage of the probe **200** between uses. The data shown was sampled every 10 seconds over a 10 minute (600 second) period and recorded in the memory of the logic circuit **500**. Data was transferred from the RS232 serial port **314** and imported into an Excel spreadsheet for plotting. The test subject was a 55 year old male in good health. Samples in the morning and late afternoon in a small paper cup with 5 drops transferred into the sample well. The pm samples were taken 5 hours after a mid-day meal while the am sample were taken early in the morning before any meals and at least 10 hours after the last meal. The data shows stable readings throughout the measurement period.

[0184] FIG. **17** shows a plot of the final readings after the 10 minute period and shows the trend line after 4 days. Diet was not recorded during the test period to see if this had contributed to the positive trend line. It would be simple to duplicate this process over a larger test subject sample and monitor diet to determine the effect of diet on urine pH.

[0185] The invention accurately measures small volumes of other mammalian fluids. Besides the example of urine testing explained in the text above, examples of other fluids would be saliva or blood. By utilizing the sample well **240**, the

device **100** can easily be used to monitor urine pH. A small sample of about 0.3 cc (4 or 5 drops) of urine placed in the sample well will generate an accurate urine pH reading. By utilizing the automatic recording function on the device **100**, these readings can be automatically stored and monitored so that the user can be notified if any significant changes have occurred over a period of time.

[0186] As mentioned above, the device **100** can be inserted further into the vagina and make contact with the ectocervix area of the cervix. Monitoring of pH of the cervix can be helpful criteria in determining the fertility cycle of the female. The design of the device is such that it also monitors vaginal or cervical temperature to monitor basal body temperature (BBT). It is a well know fact that BBT changes as much as 1° F. during the ovulation cycle and can be used as another indicator of the fertility cycle. The ability of the device **100** to store both the pH and temperature readings over an extended period of time allow the device and software to create a profile of the female mammals menstrual cycle. The ability of the device to transfer this data to a computer can be a valuable aid in analyzing and predicting the ovulation period for women with difficulty in conception.

[0187] The device **100** also monitors the vaginal pH which can be a useful tool in the monitoring of Estrogen or Hormone Replacement Therapy (HRT). Women during or post menopause can have elevated levels of vaginal pH without having symptoms of BV. The device **100** can easily store the vaginal pH readings prior to and during the HRT in order to assist in the effectiveness and regulation of Estrogen replacement therapy.

[0188] The inventive apparatus **100** is capable of measuring pH with an accuracy of 0.1 pH or better and can record measured pH values for future reference. The device **100** has the capability of recording multiple readings of pH values, date and time of the measurement and logging of these readings so that automatic user notification can be made should an unusual change in pH value occur. The amount of readings stored is strictly dependant on the size of memory within the logic unit. It would be easy and inexpensive to store hundreds of readings so that long term monitoring is possible. This method of monitoring recording and notification takes the guess work out of matching colors or keeping a written log of periodic readings. Reviewing this data and automatically detecting a noticeable change can provide instant feedback to the user that further testing or diagnostic procedures may be required especially if other BV symptoms occur.

[0189] The following outlines the typical measurement process when utilizing the device **100** to measure pH and/or temperature within the vagina to determine fertility and vaginal health status. The user (or other personnel) will first insert the probe **200** of the device **100** into the vagina at a desired depth and alignment. If the user desires to determine fertility status by measuring cervical pH and temperature, the user will insert the probe **200** into the vagina until the distal portion **230** of the probe **200** is adjacent and in contact with the ectocervix area of the user. Preferably, the probe **200** is inserted so that the well **240** is aligned with the ectocervix tissue and the diaphragm **270**, pH sensor **250** and temperature sensor **260** are aligned with and in contact with the ectocervix tissue. If the user desires to determine vaginal health status (such as the existence of BV or any of the other condition discussed above) by measuring vaginal pH and temperature, the user will insert the probe **200** into the vagina until the

distal portion 230 (including the well 240) of the probe 200 is adjacent and in contact with the vaginal wall of the user.

[0190] Once the probe 200 is in the desired position within the vagina, the user will initiate the measurement process pressing the appropriate control button(s) 340, 341 and/or 342 on the handle 300. When the firmware within the microprocessor 510 (which is located in the logic unit, i.e., the handle housing 301.) detects the control button depression (by receiving a measurement initiation signal) it will check to make sure that the probe 200 is electrically connected to the handle 300 through the interface connectors 417 and 517. If connected, the microprocessor 510 will then proceed to apply power from the battery 520 to the circuit 400 of the probe 200 through these interface connectors 417, 517 in order to read the contents of the VPD memory 415. The power supply from the battery 520 also enables (i.e., provides sufficient power to) the pH and temperature sensors 250, 260 and the remaining components of the circuitry 400. The processor 510 will verify that this is a proper probe assembly and that the contents of the VPD memory 415 are valid. If the firmware determines that the probe 200 has not been calibrated for an extended period of time based on the contents of the VPD memory 415 it will indicate to the user through the LCD that the simple single point pH7 calibration process utilizing the sample well 240 is required. As discussed above, the calibration process is preferably performed in the removable cap 600 in a dark environment with a solution buffered at a known pH.

[0191] Once the microprocessor 510 detects that the device 100 is ready to take measurements, the user activates the user control 340-342 that sends a "take measurement signal" to the microprocessor 510. In response, microprocessor 510 initiates the pH and temperature sensors 250, 260. The pH and temperature sensors 250, 260 then generate an analog pH signal and an analog temperature signal indicative of the measured pH and temperature within the vagina or at the ectocervix. These analog pH and temperature signals from the probe 200 are then transmitted to and processed through the analog to digital (A/D) converter 502. Once the calibration or measurement cycle has started, the microprocessor firmware 510 will determine when these A/D signals are stable and then proceed to retrieve and use parametric data (including the slope data) from the VPD memory 415 to calculate the pH value. To determine the pH value, the firmware on the microprocessor 510 will read the current measured temperature and utilize the slope data for the ambient 25C. temp and the normal body 98.6 temp to determine any pH correction factor that may be required at the current temperature. Once this calculation is complete, an output signal will be generated by the microprocessor 510 that corresponds to the correct pH and temperature values, the output signal is sent to the LCD 330 for viewing. This pH and temperature information along with the date/time stamp from the real-time clock (RTC) will also be stored in the local memory located (incorporated into the microprocessor 510) within the handle 300.

[0192] The microprocessor 510 will then proceed to update the appropriate fields within the VPD memory 415 to indicate that a measurement was taken along with the date/time stamp of that measurement. This stored VPD information is then used for the next measurement cycle to determine how long since the probe 200 has been used and/or how many measurements have been taken with this particular probe.

[0193] As mentioned above, when utilizing the device to monitor vaginal health, the device 100 will be used to take pH

and temperature measurements at the lower portion of the vaginal wall as indicated FIG. 3A. A similar process of verification and measurement as outlined above will occur for the vaginal fluid captured in the sample well. These vaginal pH and temperature measurements would most likely be taken when an instance of infection like BV, Candidiasis (yeast infection) or Trichomoniasis is suspected. These pH readings are important criteria for diagnosing any of these infections. Continued measurements can be taken after any diagnosis to determine the effectiveness of an OTC or prescribed treatment. The device 100 will also save these readings which can be downloaded for analysis. Vaginal measurements need not only be taken when an instance of infection is suspected. Normal periodic measurements can be taken and tracked by the processing unit to notify the user if any significant changes or trends have been detected over an extended period of time. This could be particularly useful for women entering menopause as vaginal pH generally rises due to the decreased amount of estrogen being produced. The firmware can detect these trends and notify the user via the LCD 330 that a noticeable change has occurred and that a visit with a physician may be required.

[0194] As also mentioned above, when using the device to monitor fertility status, the device 100 will be used to take the pH and temperature measurements at the ectocervix area. For monitoring fertility a daily measurement cycle will be taken for at least one but preferably several female mammal fertility cycles. In the human female, this cycle is typically 28 days. The fertility cycle for a typical women is generally during a 3 day window on days 11-14 of the 28 day cycle. However in women who are having a difficult time conceiving, this could be very narrow window (i.e. a window of just hours) or this window could be skewed from the normal cycle (i.e. days 17-18). In the case of a very narrow window multiple readings may need to be taken within a short period of time to provide optimal timing. After enough data has been stored in the memory within the handle 300, the firmware can then analyze the stored pH temperature and date/time stamp to determine the ovulation profile of the user. Any new data then measured can be compared against this profile to determine that an ovulation cycle is eminent or present. The data from the logic unit memory could be displayed as an output signal as a graphical indicia on the LCD 330 to show the ovulation cycle. If a segmented LCD display 330 is used, a simple indication that ovulation is imminent or in process would be displayed. This could be a flashing display or an ovulation icon. The stored data can also be downloaded to an external device like a PC. This download function is accomplished by the user selecting the proper control button 340, 341 and 342 functions to initiate this data transfer through external data ports 314 or 315.

[0195] Although an exemplary embodiment of the invention has been described in detail above, those skilled in the art will readily appreciate that the embodiment may be modified without departing from the novel advantages of the invention. The invention is not limited to the embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. An apparatus for measuring a physiological condition within a mammal comprising:
an elongated probe for insertion into a body lumen of the mammal, the probe comprising a first circuit board oper-

- ably coupling a pH sensor for measuring pH within the body lumen and generating a pH signal indicative of the measured pH, a memory device storing parametric data unique to the pH sensor and a first interface connector located at a proximal portion of the probe;
- a handle for manipulating the probe, the handle comprising a second circuit board operably coupling a microprocessor for processing the pH signal and generating an output signal based on the processing of the pH signal, a display device for displaying the output signal generated by the microprocessor, and a second interface connector;
- the probe connected to the handle in manner that allows the probe and handle to be repetitively engaged and disengaged from each other; and
- wherein when the probe is connected to the handle, the first and second interface connectors are in electrical connection so that the microprocessor can retrieve the parametric data from the memory device of the probe and receive the pH signal.
2. The apparatus of claim 1 wherein the pH sensor is an ion-sensitive field effect transistor (ISFET).
 3. The apparatus of claim 2 wherein the parametric data includes ISFET slope data.
 4. The apparatus of claim 2 wherein the parametric data includes first ISFET slope data determined at ambient temperature and second ISFET slope data determined at normal body temperature.
 5. The apparatus of claim 4 wherein the first and second ISFET slope data is based on at least three points of pH parametric data.
 6. The apparatus of claim 1 further comprising:

the probe comprising a temperature sensor for measuring temperature within the body lumen and generating a temperature signal indicative of the measured temperature, the temperature sensor operably coupled to the first circuit board; and

wherein the microprocessor processes the temperature signal and generates the output signal based on the processing of the pH signal and/or the temperature signal.
 7. The apparatus of claim 6 wherein the pH sensor is an ISFET and the parametric data includes first ISFET slope data determined at ambient temperature and second ISFET slope data determined at normal body temperature.
 8. The apparatus of claim 6 wherein the elongated probe has a distal portion and a proximal portion, the pH sensor and the temperature sensor located at the distal portion and the first interface connector is located at the proximal portion.
 9. The apparatus of claim 8 wherein the handle further comprises a socket forming a passageway into the handle, the second interface connector aligned with the socket, and wherein when the probe is connected to the handle, the proximal portion of the probe extends into the socket of the handle.
 10. The apparatus of claim 9 wherein the probe and the handle are connected together by one of a tight-fit engagement, a threaded engagement, and a snap-fit engagement.
 11. The apparatus of claim 8 wherein the probe extends along a longitudinal axis, and wherein the temperature sensor and pH sensor are aligned along an axis that is substantially parallel to the longitudinal axis.
 12. The apparatus of claim 6 wherein the handle further comprises a power source located within the handle, the
- power source providing power to the second circuit board and to the first circuit board when the probe is secured to the handle.
13. The apparatus of claim 12 wherein the handle further comprises user controls located on the handle and operably coupled to the second circuit board.
 14. The apparatus of claim 6 wherein the probe further comprises a first internal chamber, a second internal chamber, and a diaphragm, the first circuit board located within the first internal chamber, and the second chamber being hermetically sealed and filled with an electrolyte solution buffered at a known pH, and the diaphragm having a first portion in contact with the electrolyte solution and a second portion exposed to the body lumen.
 15. The apparatus of claim 14 wherein the probe extends along a longitudinal axis and wherein the temperature sensor, the pH sensor and the diaphragm are aligned along an axis that is substantially parallel to the longitudinal axis.
 16. The apparatus of claim 15 wherein the temperature sensor, the pH sensor and the diaphragm are located within a well formed into a distal portion of the probe.
 17. The apparatus of claim 16 wherein the temperature sensor, the pH sensor and the diaphragm are located on a substantially planar floor of the well.
 18. The apparatus of claim 1 wherein the body lumen is the vagina and the handle further comprises a second memory device operably coupled to the second circuit board, the second memory device storing algorithms for identifying a fertility period based on cervical pH and/or temperature.
 19. An apparatus for measuring a physiological condition within a mammal comprising:

an elongated probe for insertion into a body lumen of the mammal, the probe comprising a first circuit board operably coupling an ion-sensitive field effect transistor (ISFET) for measuring pH within the body lumen and generating a pH signal indicative of the measured pH, a temperature sensor for measuring temperature within the body lumen and generating a temperature signal indicative of the measured temperature, a diaphragm in contact with an electrolyte solution buffered at a known pH, a memory device storing ISFET slope data at both ambient temperature and normal body temperature for the ISFET, and a first interface connector located at a proximal portion of the probe;

a handle for manipulating the probe, the handle comprising a second circuit board operably coupling a microprocessor for receiving the pH and temperature signals and generating an output signal based on the processing of the pH and temperature signals and the ISFET slope data, a display device

for displaying the output signal generated by the microprocessor, and a second interface connector;

the probe connected to the handle in manner that allows the probe and handle to be repetitively engaged and disengaged from each other; and

wherein when the probe is connected to the handle, the first and second interface connectors are in electrical connection so that the microprocessor can retrieve the ISFET slope data from the memory device of the probe and receive the pH and temperature signals.
 20. The apparatus of claim 19 wherein the elongated probe has a distal portion and a proximal portion, the ISFET, the

temperature sensor and the diaphragm located at the distal portion and the first interface connector located at the proximal portion.

21. The apparatus of claim 20 wherein the handle further comprises a socket forming a passageway into the handle, the second interface connector aligned with the socket, and wherein when the probe is connected to the handle, the proximal portion of the probe extends into the socket of the handle.

22. The apparatus of claim 21 wherein the probe and the handle are connected together by one of a tight-fit engagement, a threaded engagement, and a snap-fit engagement.

23. The apparatus of claim 19 wherein the probe extends along a longitudinal axis, and wherein the temperature sensor, the diaphragm and the ISFET are aligned along an axis that is substantially parallel to the longitudinal axis.

24. The apparatus of claim 19 wherein the temperature sensor is a thermistor covered by a metal cap that is exposed through a first opening in a wall of the probe, wherein the ISFET is exposed through a second opening in the wall of the probe, and wherein the diaphragm is exposed through a third opening in the wall of the probe.

25. The apparatus of claim 24 wherein the probe extends along a longitudinal axis, and wherein the first, second and third openings in the wall of the probe are aligned along an axis that is substantially parallel to the longitudinal axis.

27. The apparatus of claim 24 wherein a space between the thermistor and the metal cap is filled with a thermally conductive epoxy that is not electrically conductive.

28. The apparatus of claim 2 wherein a seal is formed between each of the metal cap and the ISFET and the wall of the probe so that fluids from the body lumen can not reach the second printed circuit board through the first and/or second openings.

29. The apparatus of claim 24 wherein the temperature sensor, the pH sensor and the diaphragm are located within a well formed into a distal portion of the probe.

30. The apparatus of claim 19 wherein the handle further comprises a power source located within the handle, the power source providing power to the second circuit board and to the first circuit board when the probe is secured to the handle.

31. The apparatus of claim 30 wherein the handle further comprises user controls located on the handle and operably coupled to the second circuit board.

32. The apparatus of claim 19 wherein the body lumen is the vagina and the handle further comprises a second memory device operably coupled to the second circuit board, the second memory device storing algorithms for identifying a fertility period based on cervical pH and/or temperature.

33. An apparatus for measuring a physiological condition within a mammal comprising:

a probe for insertion into a body lumen of the mammal, the probe comprising:

an elongated tubular housing extending along a longitudinal axis from a proximal end to a distal end, the elongated tubular housing having a first internal cavity;

a first circuit board located within the first internal cavity;

a pH sensor for measuring pH within the body lumen located at a distal portion of the elongated tubular housing, the pH sensor generating a pH signal indicative of the measured pH and operably coupled to the first circuit board;

a temperature sensor for measuring temperature within the body lumen located at the distal portion, the temperature sensor generating a temperature signal indicative of the measured temperature and operably coupled to the first circuit board;

a first memory device storing parametric data unique to the pH sensor, the memory device housed within the internal cavity of the elongated tubular housing and operably coupled to the first circuit board; and

a first interface connector located at a proximal portion of the elongated tubular housing and operably coupled to the circuit board;

a handle for manipulating the probe, the handle comprising:

a second housing having a second internal cavity and a socket forming a passageway into the second internal cavity;

a second circuit board located within the second internal cavity;

a microprocessor located within the second housing and operably coupled to the second circuit board for receiving and processing the pH signal and the temperature signal, the microprocessor generating an output signal based on the processing of the pH signal and the temperature signal and the parametric data;

a power source located within the second housing and operably coupled to the second circuit board;

user controls located on the second housing and operably coupled to the second circuit board;

a display device operably coupled to the second circuit board for displaying the output signal generated by the microprocessor;

a second interface connector operably coupled to the circuit board and aligned with the socket; and

wherein the probe is removably secured to the handle, the proximal portion of the elongated tubular housing extending into the socket of the second housing so at the first and second connectors are in electrical connection.

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专利名称(译)	用于确定哺乳动物体内生理状况的装置，方法和系统		
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摘要(译)

一种用于基于pH和/或温度测量确定哺乳动物内的生理状况的系统，方法和设备。在一个方面，本发明涉及一种用于测量哺乳动物体内生理状况的装置，包括：用于插入哺乳动物体腔的探针，该探针容纳第一电路板，该第一电路板可操作地连接pH传感器以测量pH值。体腔并产生指示测量pH的pH信号，存储器装置存储pH传感器特有的参数数据，以及位于探头近端部分的第一接口连接器；用于操纵探针的手柄，手柄容纳第二电路板，该第二电路板可操作地连接微处理器以处理pH信号并基于pH信号的处理产生输出信号，标记装置用于传送由微处理器产生的输出信号，和第二个接口连接器；探针连接到手柄上的方式允许探针和手柄重复啮合和脱离；并且其中当探针连接到手柄时，第一和第二接口连接器可操作地连接，使得微处理器可以从探针的存储器装置检索参数数据并接收pH信号。

