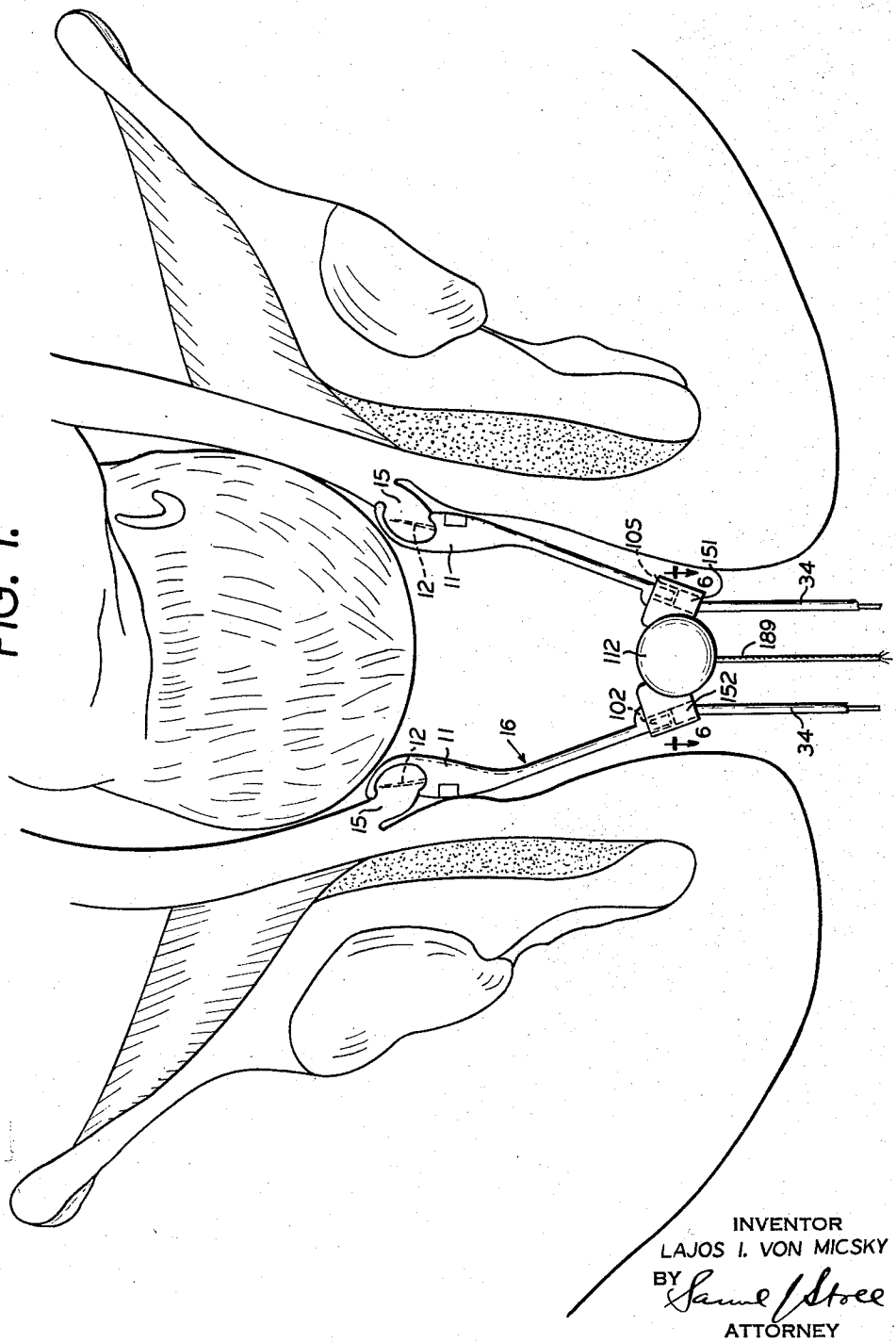
Feb. 9, 1960 L. I. VON MICSKY 2,924,220

CERVICOMETER

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FIG. 1.



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FIG. 2.

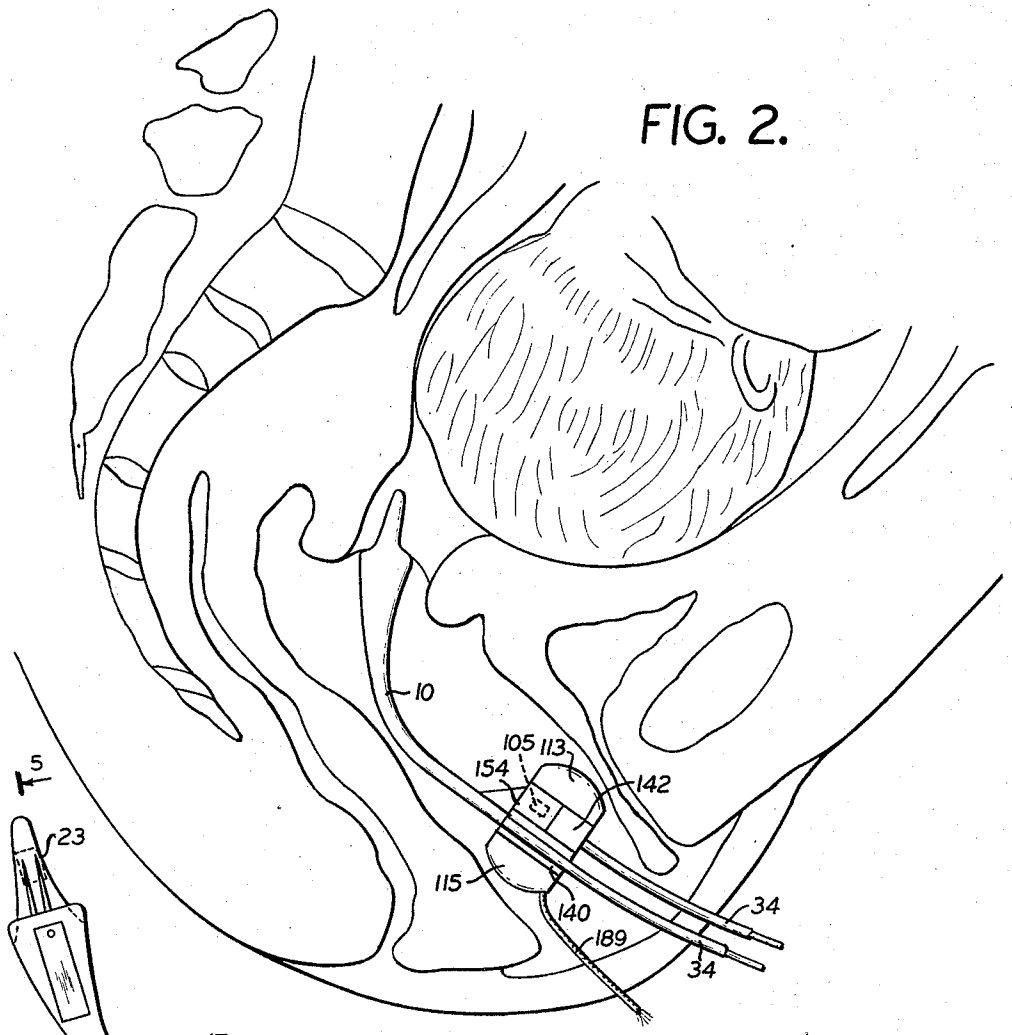


FIG. 3.

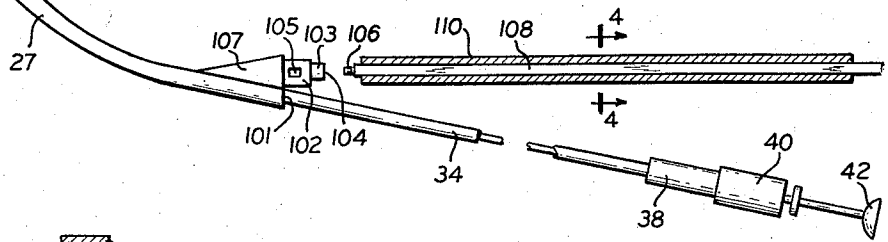




FIG. 4.

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CERVICOMETER

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FIG. 7.

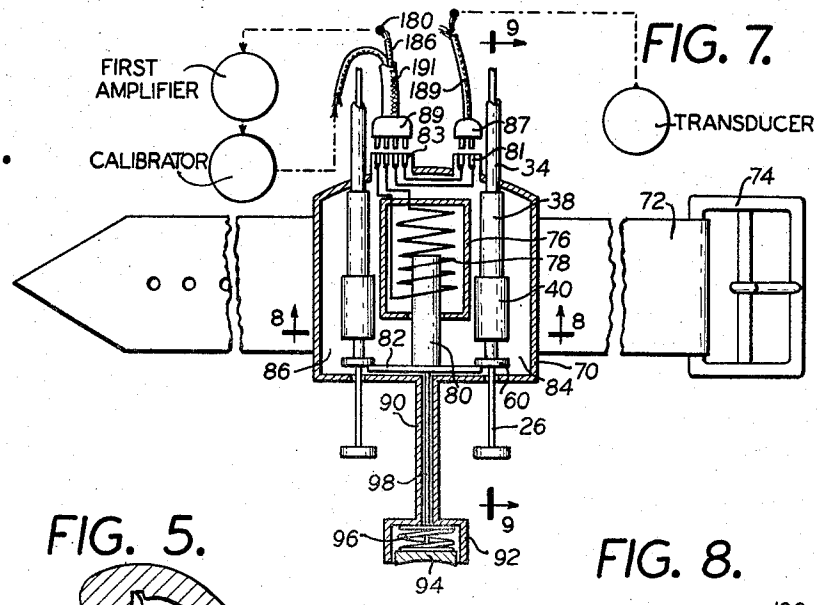


FIG. 9.

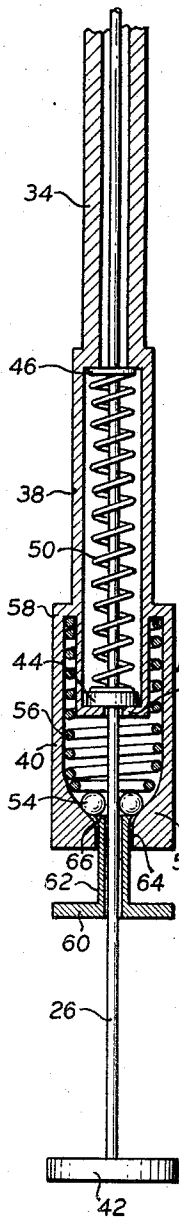


FIG. 5.

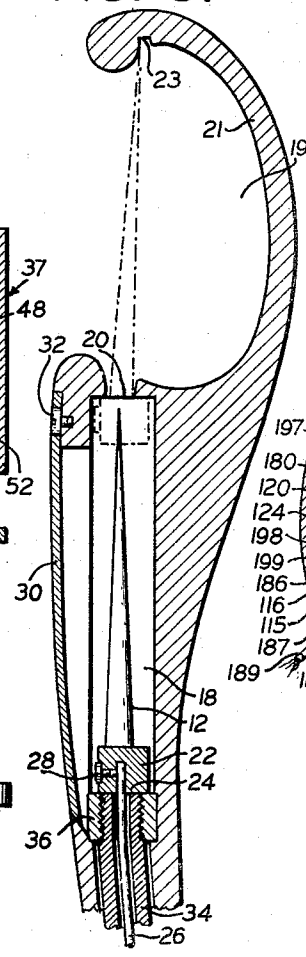


FIG. 8.

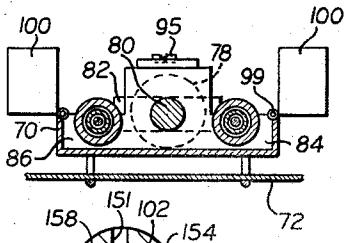
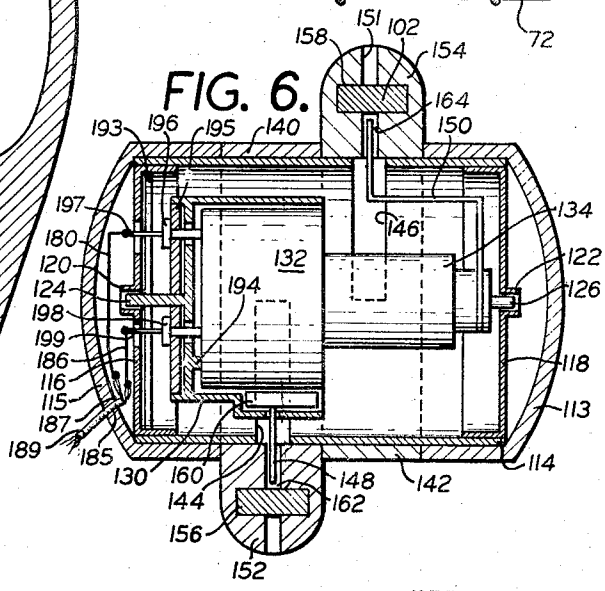


FIG. 6.



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CERVICOMETER

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FIG. 10.

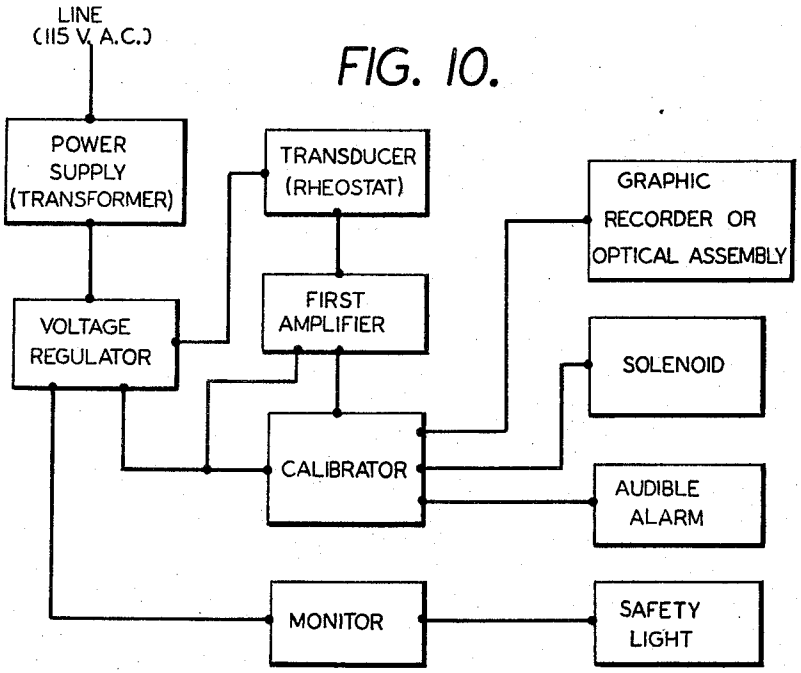
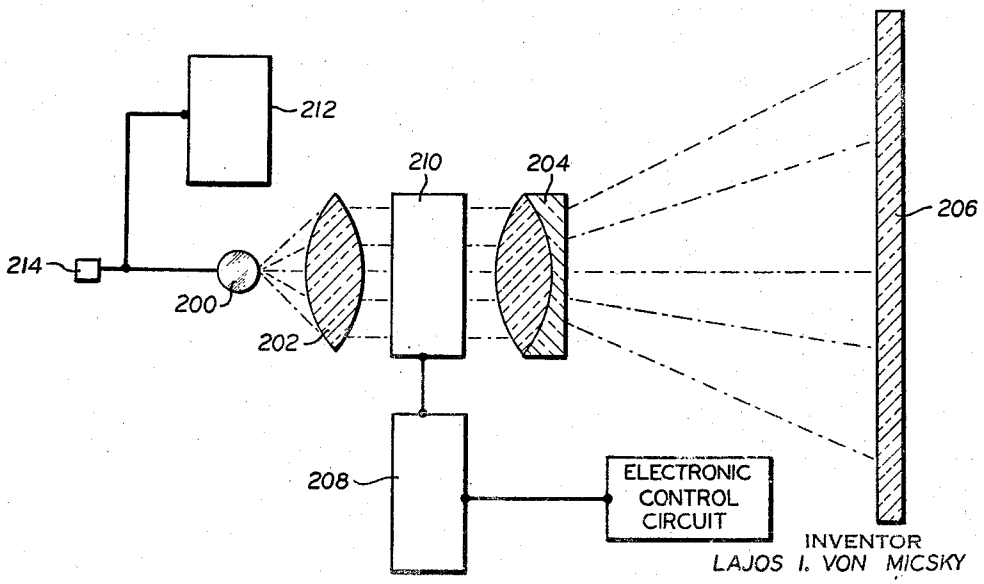


FIG. 11.



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CERVICOMETER

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FIG. 12.

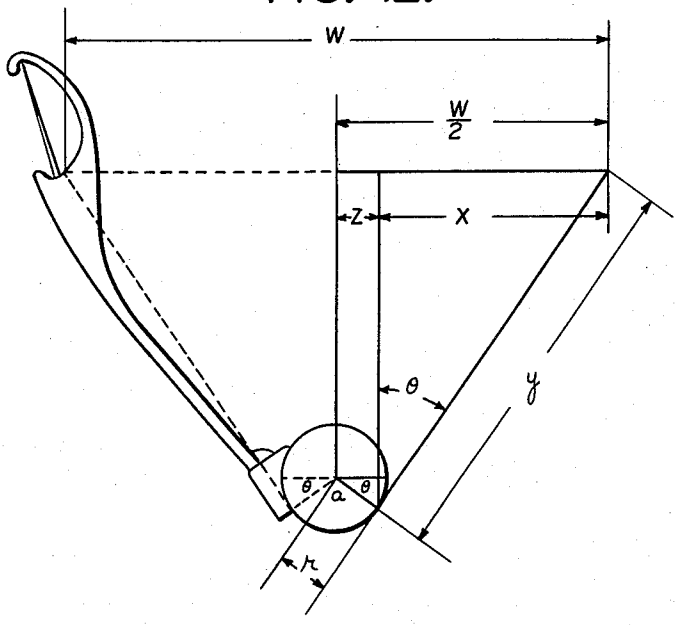


FIG. 13.

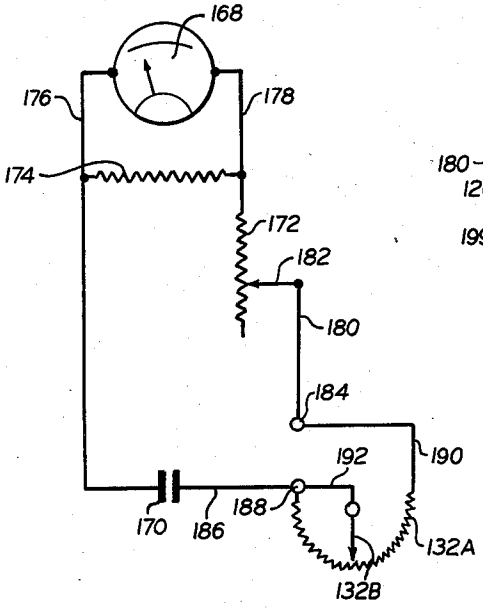
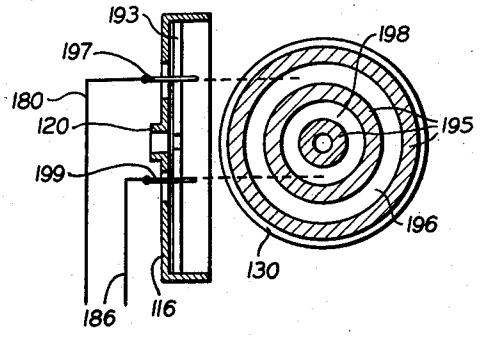


FIG. 14.



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United States Patent Office 2,924,220 Patented Feb. 9, 1960

2,924,220

CERVICOMETER

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Application February 20, 1959, Serial No. 794,658

9 Claims. (Cl. 128—361)

This invention relates to an obstetrical instrument. More particularly, it is directed to be an electronic cervicometer for measuring, registering, recording and signaling dilation of the cervix uteri in childbirth.

During labor it is important to know the extent and progress of dilation of the cervix. At the present time this information is obtained by means of digital examinations which are taken at periodic or random intervals. The attending physician utilizes the vaginal or rectal route. The measurements thus obtained are expressed in terms of the number of fingers which may be inserted into the cervix, or in centimeters, estimated by palpating the opposite rims of the cervix with a finger introduced into the rectum. This procedure has several disadvantages. It is at best haphazard and constitutes nothing more than a "spot checking" of a continuous progressive development. This produces inaccurate results, and the margin of error varies in accordance with the skill and experience of the person taking the measurements. Moreover, the measurements cannot be defined with such exactitude as to enable one person (the attending nurse) to report them accurately to another (the attending physician). Aside from the foregoing, digital examination produces considerable discomfort and even pain to the patient and it is unsatisfactory in many other respects known to those who practice and experience the method.

The main object of this invention is to provide a combined electro-mechanical and electronic device of the character described, which will continuously and accurately measure the extent of cervical dilation and register the same precisely and clearly in such a manner as to enable the attending physician or nurse to take progress readings at prescribed intervals, or record the progress of dilation continuously during the entire labor. By the use of this device the human error is eliminated both in the taking and communication of such measurements.

Another object of this invention is to provide a compact, rugged, and sterilizable electro-mechanical instrument of the character described which may be carried into the patient's vagina and attached to the cervix by needles without pain or injury to the patient.

A further object of this invention is to provide a combined electro-mechanical and electronic device which, in addition to measuring and registering the dilation of cervix, provides means for signaling the attending nurse or physician when the desired extent of dilation is obtained.

The signaling means may give audible or visible signals in the immediate vicinity of the patient or may be communicated to other stations or locations in the hospital where the device is used. With this feature there is no need to watch continuously the registering instruments. It suffices merely to check the reading from time to time, and to rely ultimately upon the signaling means for adequate notice of completion of the desired dilation. Another object of the invention is to provide a combined electro-mechanical and electronic device of the character described, which in addition to measuring, registering, recording and signaling the dilation of the cervix, incorporates safety features for the protection of the mother and child.

One of these safety features is the automatic retraction of needles from cervical tissue upon completion of the desired extent of dilation. This feature is intended to protect the patient and child against the contingency of the attending nurse or physician being occupied elsewhere at the time when dilation is completed. It also will be a safety factor in cases of pathologically rapid deliveries, so-called "precipitate deliveries."

The other feature to protect the patient is a safety circuit. Should the control fail to maintain proper voltage, said safety circuit will switch on a safety light and automatically remove all voltage from the transducer and registering circuits, eliminating thereby all danger of electrical shock to mother and child.

Still another object of this invention is to provide a registering instrument of the character described which as a result of proper combination of its optical and electrical components, will allow not only registering the extent of the cervical dilation but also visualization of cervical movements.

The potential uses of the instrument herein described and claimed are manifold. It is intended for clinical use in connection with individual patients. It is, however, also useful as an academic tool for objective study of labor forces as reflected by cervical dilation, and for the study of the effect on labor of such various factors as drugs, anesthetics, hormones, hypnosis and psychosomatic influence.

Other objects and advantages of this invention will in part be obvious and in part be hereafter pointed out.

The electronic cervicometer herein described and claimed comprises several major component parts, each with a specific function. Their combined and correlated operation is the function of the entire device as a unit which can be briefly stated as follows:

The intravaginally applied electro-mechanical instrument, best described as a "transducer caliper," is provided with a pair of lever arms which at one end are detachably secured by needles to the opposite rims of the cervix, and at the other end are connected to a potentiometer to which a small voltage is applied. As the cervix dilates, the angular distance between its arms increases but because of a translatory movement of the pivot point of the lever arms of the instrument, the voltage output is non-linear with respect to the dilation (distance between opposite points of cervical rim). This voltage is applied to an electronic unit, the amplifier tubes of which are based in such a way that they will compensate for the non-linear input from the potentiometer and provide linear current for the registering instruments. Said unit will also operate a signaling circuit and the electric release mechanism for the automatic retraction of the tissue-engaging needles.

The registering instruments which can be used separately or simultaneously are of various types, each serving a different purpose. A calibrated milliammeter serves for indicating cervicial dilation in centimeters. An optical assembly permits visualization of cervical movements besides providing measurement. A graphic recorder will render continuous graphs on the progress of cervical dilation during entire labor.

The invention is illustrated in the accompanying drawing in which:

Fig. 1 is an anteroposterior anatomical view of the pelvic region during the process of labor showing the herein described and claimed transducer caliper in situ (inserted into the vagina and its arms attached by tissue engaging needles to the opposite rims of the cervix at 3:00 and 9:00 o'clock, respectively).

Fig. 2 is a lateral anatomical view (90 degrees removed from the view of Fig. 1 showing transducer caliper in situ).

Fig. 3 is partly exploded, partly sectional view of one of the arms of the transducer caliper with the cable assembly and extension bar.

Fig. 4 is a cross-sectional view on the line 4—4 of Fig. 3.

Fig. 5 is an enlarged fragmentary longitudinal section on the line 5—5 of Fig. 3 showing the details of the socket portion of one of the arms of the transducer caliper.

Fig. 6 is an enlarged sectional view through the potentiometer and its cylindrical housing of the transducer caliper.

Fig. 7 is a fragmentary sectional view through the automatic release mechanism which automatically retracts needles from the cervical tissues when dilation is completed.

Fig. 8 is a sectional view on the line of 8—8 of Fig. 7.

Fig. 9 is a sectional view on the line 9—9 of Fig. 7.

Fig. 10 is a block diagram of the electronic unit and its correlation to the rest of the electrical components of the electronic cervicometer.

Fig. 11 is a schematic drawing of an optical assembly which may be used in connection with the basic invention herein claimed, said optical assembly being adapted to provide accurate measurements and visualization of cervical movements on a calibrated ground glass screen.

Fig. 12 is a geometrical representation of the transducer caliper.

Fig. 13 is the circuit diagram of the cervicometer in its simplest form composed only of a transducer caliper in a circuit with a dry cell and with a milliammeter which is empirically calibrated in terms of distance in order to compensate for the non-linear voltage output of the transducer caliper.

Fig. 14 is a schematic representation of the sliding ring contactor and the parts of the cylindrical casing on which it is mounted. The parts supporting the wiper springs are represented in the lateral view; those supporting the contactor rings are represented in the front view.

Referring more particularly to the accompanying drawings in which the corresponding parts are indicated by identical characters of reference in the several figures it can be seen on Figures 1, 2, 3 and 5 that the intravaginally applied electromechanic instrument designated from now on as a "transducer caliper" is composed of the following major parts:

(1) A pair of lever arms 10 for the mechanical transmission of the movements of the cervix to the pivoted and fixed elements of a potentiometer.

(2) A pair of needles 12 extending through socket portion of said arms for securing them to the cervix.

(3) A cable assembly 25 for remote control of needles.

(4) A potentiometer in a waterproof housing 112 to which said arms are connected.

The arms 10 are made of stainless steel and are provided with two curves, a cephalic curve in the frontal plane and a pelvic curve in the sagittal plane. The cephalic curve 16 corresponds to the outline of the fetal head and serves to prevent distortions in readings at dilations greater than 6 cm. The pelvic curve 17 corresponds to the pelvic axis and serves to eliminate distortions which would arise because of specific anatomical conditions, if the curved nature of the pelvic axis were not to be taken into consideration in the design of the arms. The cephalic curve can best be seen on Fig. 1 and the pelvic curve on Figs. 2 and 3.

Each of the arms is provided at the forward end with a socket portion 11. The socket portion has a socket cavity 19 which is adapted to receive the opposite lips or rims of the cervix. This can best be seen in Fig. 1, where said lips or rims are designated by the reference number 15.

It can be observed that the socket portion of each arm is provided with an elongated compartment 18 extending longitudinally. Two small slits 20 at the forward end of said compartment 18 provide communication between said compartment and the socket cavity. The pointed forward end of a pair of needles 12 projects through the said slits 20 into the socket cavity. It will be seen on Fig. 5 that in their retracted position (indicated by solid lines) the needles are disposed within said compartment 18 and in their projected position (indicated by broken lines) said needles extend into the socket cavity. A slot or recess 23 situated on a ball pointed projection of the socket portion performs the function of receiving the needle points to protect the surrounding tissues from injury.

The base or back of the needles is supported on a block 22 which is slidably mounted within compartment 18 said block is provided with a hole 24 which is generally coaxial with the needles 12, and projecting into said hole is the forward end of a flexible cable 26. A set-screw 28 secures said forward end of cable 26 to said block 22. It will be seen that a cover plate 30 is provided on the socket portion of the arm to close the compartment 18. The lower margin of said cover plate is beveled and fits into a corresponding lip of the lower margin of the opening for the cover plate. This arrangement with a screw 32 provides a water-proof closure for compartment 18. The cover plate may be removed to expose the several components abovementioned which are enclosed within said compartment, allowing for the change of needles, a thorough cleaning, and submerged sterilization of the compartment 18.

The socket portion of the arm just described continues in a tubular shank 27 which is provided at its lower end with an opening 101 through which the cable 26 incorporated in a flexible tube 34 is introduced to be connected to aforementioned block 22. At its lower end adjacent to opening 101 the tubular shank is also provided with a boss 102 which fits into rectangular sockets 156—158 of lugs 152—154 of sliding rings 140—142. These sliding rings are part of the housing of the potentiometer to be described later. On the side of the boss a spring clip 105 is mounted in a groove and fits into a slot 151 on the side of lugs 152—154 attaching thereby the arms to said sliding rings 140—142. Boss 102 is also provided with a lip 107 which when the arms are connected to sliding rings rests on the top part of the lug and together with the spring-clip locks said boss into rectangular socket of lug.

The transducer caliper is designed as slim as possible and its parts are so proportioned that when the arms are in zero position (the two ball-pointed projections of socket portion resting against each other) the width of the whole instrument is less than that of two fingers used in course of routine pelvic examinations. The projected lengths of the arms from the boss to slits 20 in socket cavity is 7 cm. The overall length due to the pelvic and cephalic curve is somewhat more.

The cable assembly comprises a cable 26 slidably mounted within a flexible tube 34, an actuating button 42, a coil compression spring to effect retraction of cable; a lock 37 and a release button 60 with its tubular shaft 62. Cable 26 at its forward end is fixed by said screw 28 to block 22 and flexible tube 34 is secured at its forward end by a screw threaded engagement to a sleeve 36 mounted within compartment 18. The forward or upper third of cable and flexible tube is housed inside of a tubular shank of arms. The outer or lower end of the tube 34 is provided with an enlarged portion 38, housing a coil spring 50 to effect retraction of cable. Connected to said enlarged portion is a generally cylindrical housing 40 for lock 37 of the cable assembly. This is best seen in Fig. 9. It will also be seen that cable

26 projects through enlargement 38 and housing 40 and is provided at its outer end with an actuating button 42.

A ring 44 is welded to wire or cable 26 enclosed in enlargement 38. Said enlargement is provided at its forward end with an annular shoulder 46 and it is also provided at its back end with an annular flange 48. A coiled compression spring 50 encircles cable 26 within enlargement 38; one end of said spring bearing against shoulder 46 and the opposite end bearing against ring 44. Since said ring is secured to cable 26, the effect of this arrangement is to cause said wire to be spring-urged in rearward direction (downwardly as viewed in Fig. 9). Flange 48 serves as a stop to ring 44. Since needle 12 is secured to block 22 and since said block is secured to the forward end of wire 26, the net effect of the foregoing is to cause retraction of said needle to its solid line position shown in Fig. 5.

Further reference to Fig. 9 will disclose the fact that a lock 37 is provided to hold wire 26 in any selected forward position against the action of spring 50. When button 42 is manually pushed to move wire 26 forward in order to cause needles 12 to engage the cervical tissue, such forward movement takes place against the action of spring 50 and causes said spring to load. It will now be observed that housing 40 is provided with a generally tapered or conical end wall 52 and with a plurality of balls 54 seated against said tapered wall. A coiled compression spring 56 bears at one end against the front wall 58 of housing 40 and at its opposite end against balls 54. The balls are therefore wedged between the tapered wall and wire 26 and this in turn locks the wire against the action of spring 50.

Fig. 1 shows arms in engagement with the cervical lips and needles 12 transpiercing said lips to prevent dislodgment of said arms from said lips. Wires 26 would thus be positioned in their forward position against the action of springs 50. When it is desired to disengage needles from the cervical lips, release buttons 60 are actuated, either manually or by means hereinafter described. Referring again to Fig. 9 it will be observed that each release button 60 is provided with tubular shank 62 through which wire 26 extends. The forward end of shank 62 passes through an opening 64 at the back end of housing 40. Said tubular shank is provided with an enlarged end portion 66 which prevents it from being pulled out of said opening 64. Enlarged end portion 66 of said shank 62 performs the additional function of engaging balls 54 in order to release them from wire 26. Such release occurs when release button 60 is pushed forwardly (upwardly as viewed in Fig. 9) and balls 54 are thereby moved out of wedging relation between the wire 26 on the one hand and the tapered end wall 52 on the other hand. Spring 50 is thereby rendered free to retract wire 26 and with it the needles 12.

As has been above stated this procedure may be performed manually or by other means and reference is now made to Figs. 7 and 8 for showing an electro-mechanical apparatus for accomplishing this result.

A casing 70 provided with two spring-urged hinged covers 100 is mounted on a belt which may be placed around the thigh of the patient and is held in place by suitable fastening means such as buckle 74. A solenoid 76 is mounted within said casing 70 between the two compartments 84 and 86 which are of such dimensions and shape that they will accommodate the enlarged portions 38 and housing 40 of the two cable assemblies above mentioned. These in turn are held in compartments 84 and 86 by pressure of spring urged covers 100. A preferred type of lock 95 mounted on top of casing, secures the covers in their closed position. The solenoid is provided with a coil 78 and a plunger 80 in the conventional manner. A bridge 82 is secured at its center to the plunger and its ends are in contact with the release buttons 60. When the solenoid is energized, plunger 80 is retracted into the coils and bridge 82 is thereby caused to actuate the release buttons, causing these latters to release wires 26 from their respective locking balls 54. Springs 50 are thereby released sufficiently to enable them to retract wires 26 and needles 12 connected therewith.

The mechanism shown in Fig. 7 may also be operated manually. A tubular stem 90 is provided on casing 70 and a hole is provided in the wall of said casing to provide communication between said tubular stem 90 and the inside of the casing. At the outer end of said tubular stem is a cup 92 adapted to receive a button 94 and a compression spring 96. Attached to said button is a shank 98 which extends through tubular stem 90 and into engagement with bridge 82. When button 94 is pressed against the action of spring 96 shank 98, acting through bridge 82 actuates the two release buttons 60 without the intervention of the solenoid.

Two receptacles 81 and 83 are provided on casing 70 to receive plugs 87 and 89 respectively. As it is apparent from Fig. 7 conductors 180 and 186 incorporated in cable 189 will continue in cable 191 toward the first amplifier. Cable 191 incorporates two more conductors which connect solenoid 76 to the calibrator. The purpose of this arrangement is to permit disconnection of different units of the device for easier handling and to eliminate a maze of cables entangling each other.

The structural features shown in Figs. 7 and 8 are not critical and may be modified as desired. It is of course understood that, upon the advent or approach of full dilation the attending physician will himself disengage the apparatus from the cervix, and it is intended that the apparatus be used in this manner. The automatic operation above described, wherein the solenoid disengages the apparatus from the tissues of the patient, is intended mainly for precautionary purposes, to avoid risk of injury to the patient or to the fetus should the physician happen not to be in attendance at the moment of full dilation.

Turning now to Fig. 1 it will be noted that, although the dimensions of the transducer caliper were reduced to the smallest possible size the cylindrical casing 112 of the potentiometer is still too bulky to allow the attachments of the arms to the cervix under vision without using large vaginal retractors and applying on them such a force that would cause considerable pain to the patient. In order to solve this problem the apparatus was so devised that the arms are detachably fixed by a spring clip into rectangular sockets 158—156 of sliding rings 140—142 of cylindrical casing 112, allowing thereby the separate introduction of the arms and the cylindrical casing 112 into the vagina. To facilitate the attachment of the relatively short arms to the cervical tissue an extension bar 108 was devised, mounted within sleeve 110. One such extension bar is shown in Figs. 3 and 4. It will there be seen that the boss 102 mounted at the back end of each arm 10 has a quadrangular projection 103 which has the same dimensions as the extension bar 108. This quadrangular projection has a threaded socket 104 which is adapted to receive the threaded end 106 of the extension bar 108. The extension bar is attached to the arm 10 by screwing the threaded end 106 of said bar 108 into threaded socket 104 of boss 102 and sliding the sleeve 110 over quadrangular projection 103 of boss. It is by means of said extension bar that arm 10 may be guided into operative position relative to the cervix of the patient.

This procedure which is actually a minor obstetrical operation is carried out observing the rules of aseptic technique. The transducer caliper with the arms detached from the cylindrical casing and the extension bars are sterilized by submerging them for 15 min. into C.I.R. (or other similar) sterilizing solution. The patient is placed in lithotomy position and after a surgical perneal preparation she is draped and the cervix is exposed by the means of vaginal retractors. The extension bars

are attached to the arms and, using the bar as a handle, the left arm is introduced to the vagina and placed so that the ballpointed projection of the socket portion will be inserted into the cervical canal and the portion of the rim corresponding to 3:00 o'clock will be accommodated in the socket cavity. Now by pressing the actuating button **42** of cable assembly the needles will transpierce the cervical tissue and securely attach the lever arms to the cervix. As it can be seen on Fig. 3 two needles are supported on each needle block **22**. The plurality of needles diminishes the possibility that the needles get separated from cervical tissue and the arms dislodged in the course of labor. Since the pain perception of the cervix is negligible no anaesthesia will be required for this procedure and due to the size of needles the trauma inflicted is inconsequential.

By slipping rectangular sockets **156—158** over boss **102** spring clip **105** will engage into slot **151** of lugs **152—154** fixing thereby the arms **10** firmly to the cylindrical casing **112**. Now the extension bars can be detached by sliding sleeve **110** backwards and unscrewing extension bar **108** from the threaded socket **104** of boss **102**. Now the electric release mechanism for automatic release of tissue engaging needles is fastened by the rubber belt to the patient's thigh, the hinged doors are opened, the proper position of bridge **82** checked and enlarged portion **38** and housing **40** of lock **37** will be placed in their corresponding compartment.

The foregoing description relates to the mechanical parts of the present invention. The following description will cover its electrical components in combination with such additional mechanical parts as are associated with it.

It has been stated that arms **10** are connected to a potentiometer **132**. Said potentiometer is best shown in Fig. 6 and it will be observed that it includes a cylindrical casing **112**. Said casing encloses a sleeve **114** which supports a pair of end-bearing plates **116** and **118**, respectively. Hubs **120** and **122** of said end-bearing plates support shafts **124** and **126**, respectively. Stud shaft **124** supports a bracket **130** which encloses potentiometer **132**. Shaft **126** extends through a fixed collar **134** and is connected to the movable contact element or wiper which engages the resistance element or coil of the potentiometer. It will be understood that as in all potentiometers it is immaterial whether the coil or resistance moves relative to the wiper or whether the wiper moves relative to the coil or resistance, or whether both move relative to each other.

Casing **112** comprises, in effect a pair of spaced shells **113** and **115** which are secured to the inner sleeve **114**. Between the two shells is to a pair of rings **140** and **142** respectively, these rings being mounted on said inner sleeve **114** for rotatory movement relative to each other and relative to said inner sleeve about a common axis coinciding with the axis of shafts **124** and **126**. These shafts are also coaxial with the potentiometer's coil or resistance and the potentiometer's wiper.

The various componet parts of the casing are constructed and fitted with such accuracy that the waterproofing indispensable for the protection of the potentiometer is accomplished alone by the precision fit, rendering unnecessary the use of rubber washers. The casing as well as the lever arms are made of stainless steel of 0.020" thickness which, while assuring great strucural strength, will not make the instrument heavy and will resist the corrosive action of the sterilizing solutions.

Slots **144** and **146** are provided in sleeve **114** and through said slots mechanical arms **148** and **150** provide transmission of movements between potentiometer and said rings **140—142**. Mechanical arm **150** at one end is connected to shaft **126** of the potentiometer; at the other end it projects into a hole **164** of lug **154** which is located inwardly to rectangular socket **158**. Mechanical arm **148** has a small base plate **160** which is compressed between the potentiometer and bracket **130**; its other end projects into a hole **162** in lug **152** inwardly from rectangular socket **156**. Ring **142** is thereby connected to the potentiometer's wiper and ring **140** to the potentiometer's coil. It is evident from this description that when either of said rings is moved relatively to the other ring, relative movements will take place between the coil and wiper of the potentiometer. The bracket supporting the potentiometer contains two contactor rings **196** and **198**, each connected to a terminal of potentiometer **132** and mounted on insulating disc **195**. Since there are three connections necessary for the potentiometer circuit the third connection terminal **194** would be carried directly to the metal casing of the potentiometer. When the potentiometer is installed within its casing the two contactor rings will make contact with the two wiper springs **197** and **199**, respectively. These are mounted on insulating disc **193**, which is supported by end-bearing plate **116**. The wiper springs are connected to conductors **180** and **186** respectively, which are incorporated into cable **189** and leave the casing through opening **185** located on spaced shell **115**. Waterproofing is established by the employment of a small rubber washer **187** fitting into opening **185**.

Due to its particular construction the previously described instrument has three distinctive characteristics when in operation.

(1) The lever arms are conneced to sliding rings **140** and **142**, respectively. These are so situated on sleeve **114** that they rotate around it coaxially with the potentiometer. For that reason when the arms attached to the cervix are moved apart due to the dilation of the cervix, their movements will be angular about the axis of the potentiometer and always tangent to its cylindrical casing.

(2) In the operational position the arms of the instrument are attached by needles to the cervix. The result of this arrangement is that when the dilating cervix moves the arms apart, with the increase of angle between said arms the pivot point (axis of potentiometer) moves closer to the line between the attachment points (distance to be determined).

(3) The movements of the sliding rings are transmitted by mechanical-arms to the potentiometer's coil and wiper, respectively. It follows that when the arms move apart their angular movement will cause a relative movement between the potentiometer's coil and wiper, resulting in a variation of voltage output caused by the change of resistance of said potentiometer.

Consequently when using the electronic cervicometer the dilation of the cervix (linear distance between opposite points of cervical rim) is determined by measuring the change of angle between the arms as it is reflected by a variation in voltage output. It will now be apparent that the electronic cervicometer in accordance with the invention utilizes the relation between the angle and distance for measuring the unknown distance between opposite points of the rim of the cervix.

Fig. 12 is a geometrical representation of the transducer-caliper. (The outlines of the instrument are drawn on the left side of diagram for identification of the instrument's geometrically represented components.)

On this figure w denotes the distance measured; Y is the length of lever arm; A represents the axis of potentiometer; r is the radius of sliding ring and θ is the half angle of turn of wiper of potentiometer relative to its coil.

$$\frac{W}{2}=Z+X=r\cos\theta+Y\sin\theta \tag{1}$$

$$W=2r\cos\theta+2Y\sin\theta \tag{2}$$

$$\theta=\sin^{-1}\left[\frac{wy\pm r\sqrt{4Y^2-W^2+4r^2}}{2(y^2+r^2)}\right] \tag{3}$$

The change of resistance caused by the relative angular movement of potentiometer's coil and wiper is as follows:

(4) $$R=2c\theta$$

where c is the resistance measured in ohms per degree turn of potentiometer.

From ohm's law:

(5) $$E=IR$$

(6) $$E=2cI\sin^{-1}\left[\frac{wy-r^2\sqrt{4y^2-w^2+4r^2}}{2(Y^2+r^2)}\right]$$

(7) $$w=2Y\sin\frac{E}{2cI}\pm\sqrt{(Y^2-1)\sin\frac{E}{2cI}+r^2}$$

It appears from the above equations that w does not vary directly with θ. Substituting values: $r=1$ cm., $y=7$ cm. into Equation 3, and assigning values from 1 to 14 to w, a curve θ vs. w can be plotted. This proves to be a non-linear curve. Since the change of resistance and so the variation in voltage output depends on θ, it follows that the voltage output from the transducer will be non-linear. A milliammeter in circuit with the transducer can be calibrated in terms of distance for accurate indication of cervical dilation, but the recorder and also the aforementioned optical assembly require linear current. For that reason a correction should be made to compensate for the non-linear voltage input from the potentiometer. This can be obtained by selecting an amplifier tube for the electronic unit, the characteristic curve of which is approximately the mirror image of the non-linear, mathematically determined curve, and by applying the proper bias to said amplifier vacuum tubes. Another possible solution is to use a non-linear potentiometer, designed in such a way that it would compensate adequately for the non-linear relation between w and θ and thus provide a linear voltage output.

Cervicometers composed of only a transducer caliper, a simple circuit with a dry cell, and an impirically calibrated milliammeter can be made very compact and inexpensive. Although they lack a great number of features of the electronic cervicometer they will constitute a very useful and practical clinical instrument.

Fig. 13 illustrates the circuit diagram of such a device. As shown on this figure the fixed resistance **174** lies across conductors **176** and **178** which are connected to the milliammeter **168**. Conductor **176** connects one side of the milliammeter to dry cell **170**. Conductor **178** connects the opposite side of the milliammeter to resistance **172** and another conductor **180** is connected to the movable contact member **182** of said resistance **172**. It will now be noted that conductor **180** is connected to a terminal or contact member **184** and another conductor **186** connects the dry cell **170** to a second terminal or contact member **188**. A pair of conductors **190** and **190** are plugged into or otherwise connected to the terminals **184** and **188** and one of said conductors is connected to the coil **132***a* of potentiometer **118**, while the other is connected to the wiper **132***b* of said potentiometer.

Referring now to Fig. 10 it shows the electronic unit in correlation with the rest of the electrical system of the device.

As it is apparent from this illustration the non-linear variation of the transducer is amplified through an electronic amplifier designated as "First amplifier." Since a linear current is required to operate the recorder or optical assembly, designated "Graphic recorder" and "Optical assembly," respectively, in Fig. 10, it is necessary to compensate for the non-linear output of the potentiometer by applying proper bias to the amplifiers. The first amplifier is biased so as to give a linear voltage output to the directly coupled calibrator. The calibrator is biased in such manner as to provide linear current output to the recorder circuit.

There are two relays in the plate circuit of the calibrator, one a thermal relay operating thirty seconds after the power switch is closed. This delay serves to protect the graphic recorder from any possible surge during the warm-up period of the vacuum tubes. The second relay performs the following functions: It removes all power from the recorder when it has reached its full scale indication; it operates a small solenoid (as shown in Fig. 7 of the drawing) which retracts the tissue-engaging needles from the cervix; and it provides a closed circuit for operation of an optional external alarm, designated "Audible or Visual alarm" in Fig. 10 of the drawing. Power is supplied to the potentiometer and amplifiers by a full wave, transformer operated power supply. Isolation from the main power line is provided by the transformer. Proper filtering is obtained with a condenser input filter system. Since the entire accuracy of the present device is dependent upon the voltage applied to the potentiometer, a gas voltage regulator tube is used to maintain a constant voltage. This is indicated in Fig. 10 of the drawing as the "Voltage regulator."

The safety circuit consists of a relay that is bridged to the voltage regulator tube of the power supply. A safety light designated as such in Fig. 10 will glow upon failure of the control to maintain a proper voltage at the regulator tube. The safety circuit will, at the same time, remove voltage from the potentiometer and registering circuits, thus removing any danger to the patient or the graphic recorder. A graphic recorder can be attached to the electronic unit to obtain a permanent record of the dilation of the cervix as a function of time. This could be useful for the research purposes specified in the general description of the apparatus.

Referring now to Fig. 11 it illustrates a registering instrument which by the proper combination of optical and electronic components, and arrangements of parts will allow not only the measurements of cervical dilation but also visualization of cervical movements.

At it is apparent from the diagram the linear current of the calibrator is introduced into a network **208** to provide the specified proper current for the commercially available automatic iris **210** which is placed between a condenser **202** and a projection lens **204**. An accurately proportional dilation of the automatic iris will correspond to any degree of dilation of the cervix. Using a proper light source **200** and a proper lens-screen distance, life-size image of the cervix can be projected on a calibrated ground glass screen **206** and all changes in cervical movements can be visually followed and measured. A blower **212** will provide the cooling system for this optical electronic assembly. The input terminal **214** is to be connected to a conventional 110 volt alternating current household line.

The usefulness of the combined electronic optical assembly is not limited to the visualization of cervical movements, but with a proper transducer it can be utilized for the visualization of the movements of other sphincters or organs with circular musculature.

It will be thus concluded that the described apparatus is a device in which the several objects of this invention are achieved and which is well adapted to meet the conditions of pratical use.

It will, of course, be understood that various changes in details of construction and arrangements of parts may be made without departing from the spirit of the invention and the broad scope of the claims.

I claim:

1. A cervicometer of the character described, comprising a pair of arms which are adapted to be inserted into the human vagina, fastening means at the forward ends of said arms to detachably connect them to the opposite lips of the human cervix, a rheostat having a fixed element and a pivoted element, the outer end of one of said arms being connected to said fixed element and the outer end of the other arm being connected to said

pivoted element, a milliammeter and a source of electric current in circuit with said rheostat and said milliammeter, whereby dilation of the cervix causes the arms to move apart and the pivoted element of the rheostat to pivot relative to the fixed element thereof and thereby to cause a change in the reading of the milliammeter proportionate to the extent of dilation of the cervix.

2. A cervicometer in accordance with claim 1, wherein the arms are provided at their inner ends with socket portions adapted to receive the lips of the cervix, the fastening means by which said arms are adapted to be attached to said lips comprising a pair of curved needles, one for each arm, said needles being spring-urged forwardly across said sockets and being provided with means for retracting them against said spring action.

3. A cervicometer, in accordance with claim 1, wherein the outer ends of the arms are connected to the fixed and pivoted elements of the rheostat by means of tubular members, said tubular members being secured, respectively, to said fixed and pivoted elements, and said outer ends of the arms being disposed within said tubular members, latch means being provided between said outer ends of the arms on the one hand and the tubular members on the other hand, to detachably secure said outer ends of the arms to said tubular members.

4. A cervicometer in accordance with claim 3, wherein a hollow housing is provided for the rheostat, said tubular members being disposed mainly within said hollow housing, elongated slots being provided in the hollow housing through which end portions of said tubular members project, said slots being adapted to permit relative pivotal movement between the two tubular members.

5. A cervicometer in accordance with claim 1, which is provided with supporting means for supporting it upon one of the thighs of the patient, automatic release means being provided which is sensitive to the spacing of the arms and which releases the fastening means on said arms from the cervical lips when dilation attains a predetermined degree.

6. A cervicometer in accordance with claim 5, wherein the automatic release means includes a solenoid which is electrically connected to the rheostat, said rheostat controlling the current which reaches the solenoid so as to actuate the solenoid at a predetermined time related to the progress of dilation.

7. A cervicometer in accordance with claim 1, wherein an audible alarm which is electrically actuated is connected to the rheostat, so as to signal full dilation to the attending medical personnel.

8. A cervicometer in accordance with claim 1, wherein the progress of dilation is represented upon a screen through an optical system, said optical system being electronically energized by amplifying means connected to the rheostat.

9. A cervicometer in accordance with claim 1, wherein a graphic recorder is connected to the rheostat, said recorder being sensitive to the flow of current through said rheostat and being thereby adapted to record the progress of dilation.

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