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(72) Inventeur/Inventor:
PALTIELI, YOAV, IL

(73) Propriétaire/Owner:
TRIG MEDICAL LTD., IL

(74) Agent: OGILVY RENAULT LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : PROCEDE ET DISPOSITIF SERVANT A CONTROLER L'EVOLUTION DU TRAVAIL PENDANT L'ACCOUCHEMENT
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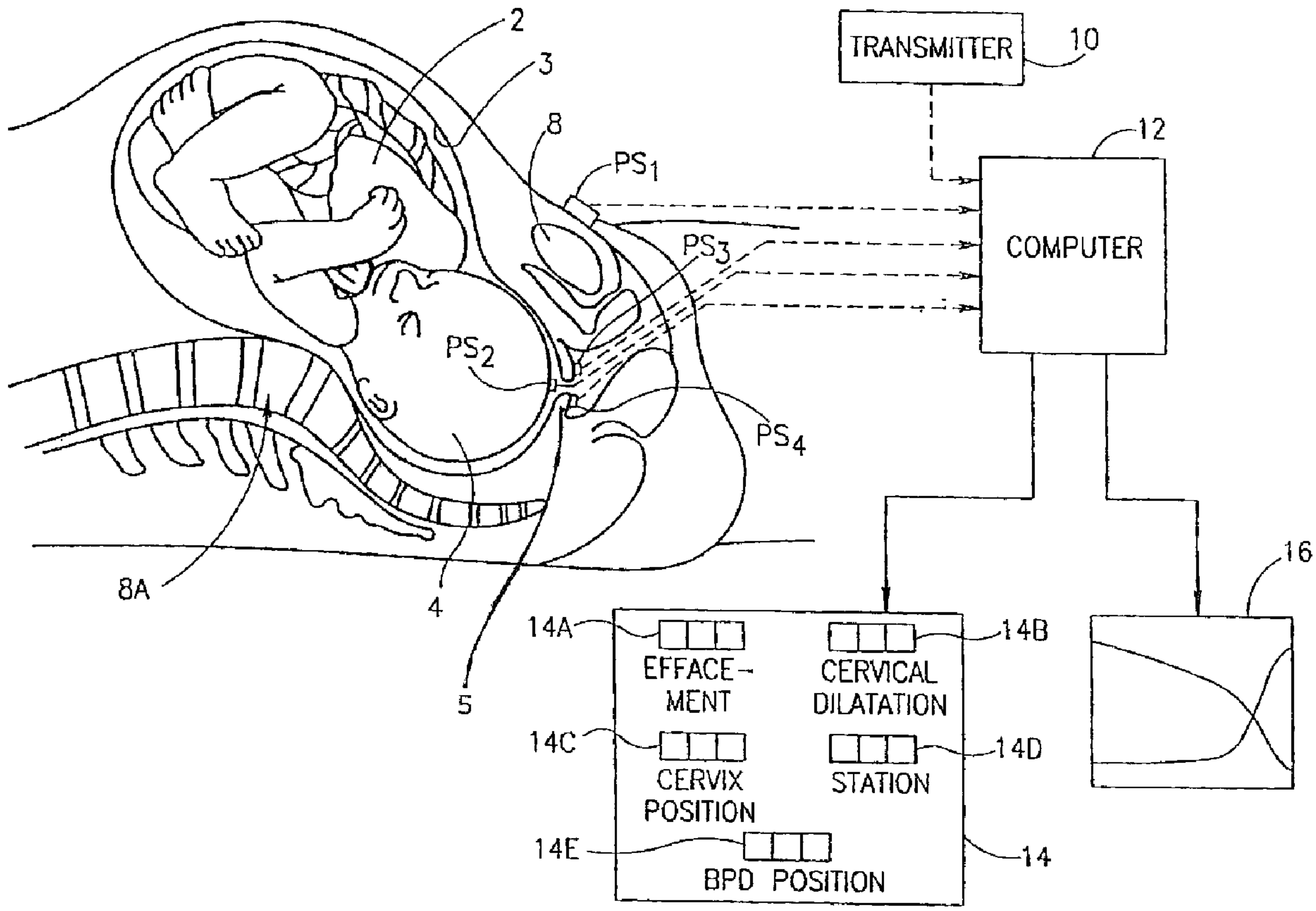

(57) Abrégé/Abstract:
A method of monitoring the progress of labor in a mother during childbirth, by attaching a position sensor to a predetermined point on the mother's pelvic bones; monitoring the location of the position sensor in three- dimensional space relative to a reference; and

(57) Abrégé(suite)/Abstract(continued):
monitoring the location of the fetal presenting part with respect to the predetermined point on the mother's pelvic bones. The location of the fetal presenting part may be indicated by a similar position sensor, or by imaging. Other conditions, such as effacement, cervical dilatation, and cervical position may also be monitored in a similar manner.

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ABSTRACT OF THE DISCLOSURE

A method of monitoring the progress of labor in a mother during childbirth, by attaching a position sensor to a predetermined point on the mother's pelvic bones; monitoring the location of the position sensor in three- dimensional space relative to a reference; and monitoring the location of the fetal presenting part with respect to the predetermined point on the mother's pelvic bones. The location of the fetal presenting part may be indicated by a similar position sensor, or by imaging. Other conditions, such as effacement, cervical dilatation, and cervical position may also be monitored in a similar manner.

METHOD AND APPARATUS FOR MONITORING THE PROGRESS OF LABOR

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for monitoring the progress of labor during childbirth.

Normal labor is generally divided into three stages: The first stage begins with the onset of labor and ends when dilatation of the cervix is complete; the second stage begins at that point and ends with the complete birth of the baby; and this is followed by the third stage which ends with the delivery of the placenta. During labor it is common to use either an external ultrasonic system for recording the baby's heart rate, and an external system for detecting the mother's uterine contractions, or an electronic system to sense the baby's heart pulses by an electrode attached to the baby's head and the mother's contractions by a pressure catheter applied to the mother inside the uterus.

However, a number of other physiological conditions of the mother and baby during labor must also be monitored in order to determine the progress of labor. These additional conditions include: (1) effacement (the thinning out of the cervix that occurs before and during the first stage of labor); (2) cervical dilatation (the increase in size of the cervical opening); (3) position of the cervix (the relation of the cervix to the vaginal axis, normally the fetal head); and (4) station (the level of a predetermined point of the fetal presenting part with reference to the mother's pelvis). The more common determination of station is the distance between the tip of the fetal head and the ischial spines which can be palpable by the physician;

but a more accurate determination of station is the distance between the bi-parietal diameter (BPD) of the fetal head and the mother's pelvic inlet.

The foregoing conditions are generally determined by a physical examination, i.e., by the insertion of a finger through the mother's vagina. However, the accuracy of such a "finger" examination is very subjective and depends to a great extent on the experience, judgment, and even finger size, of the physician. Other drawbacks in such a physical examination are that it can be done only at spaced intervals, it generally produces discomfort to the mother, and it involves a number of risks including contamination, infection, dislodgment of a fetal monitor, injury to the baby, etc. Failure to interpret the precise stage of the labor progress from the physical examination can result in injury or even death of the baby or of the mother.

Many devices have been proposed in the past for automatically monitoring these conditions. As examples, US Patent 4,476,871 proposes an elongated tube having electrodes spaced along its length to monitor cervical dilatation during labor; US Patents 4,942,882 and 5,135,006 propose a fetal monitor probe attached to the fetal head to monitor heart beat, which probe is calibrated to monitor progress of descent; US Patent 5,222,485 proposes an elongated inflatable sac to monitor the position of the fetus and the configuration of the cervix; and US Patent 5,406,961 proposes a pessary to monitor the configuration of the cervix. However, for one reason or another, none of the previously proposed devices has come into any widespread use, and the historical "finger" examination continues to be the one in common use to this day.

OBJECTS AND BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to provide a method and apparatus having advantages over the conventional "finger" examination technique for monitoring the progress of labor in a mother during childbirth.

According to one aspect, there is provided a method of monitoring the progress of labor in a mother during childbirth using a system comprising a first position sensor attached to a predetermined point in the mother's pelvic bones and a second position sensor attached to the outer tip of the fetal presenting part; the method comprising: monitoring the location of the first position sensor in three-dimensional space relative to a reference; and monitoring the location of the fetal presenting part with respect to the predetermined point on the mother's pelvic bones to provide an indication of the progress of labor by monitoring the location of the second position sensor.

According to another aspect of the present invention, there is provided a method of monitoring the progress of labor in a mother during childbirth, comprising: attaching a position sensor to a predetermined point on the mother's pelvic bones; monitoring the location of the position sensor in three-dimensional space relative to a reference; and monitoring the location of the fetal presenting part with respect to the predetermined point on the mother's pelvic bones to provide an indication of the progress of labor.

Three embodiments of the invention are described below for purposes of example. In one embodiment, the location of the fetal presenting part, and also of the opposite sides of the end of the mother's uterine cervix, are monitored by position sensors attached to these respective elements. In a second described embodiment, the latter are monitored by operating an ultrasonic transducer to image the mothers cervix and pelvic bones, and the fetal head, on a screen, and by using a position sensor on the ultrasonic transducer, and a marker for marking the screen, to locate the positions of these elements. A third embodiment is described utilizing both the four position sensors applied to the mother and the fetal presenting part, and a fifth position sensor applied to an ultrasonic transducer for imaging and locating the mother's cervix and pelvic bones and the fetal head

According to further features in the described first and third embodiments, the cervical dilatation of the mother's cervix is continuously indicated by continuously monitoring the positions of the position sensors applied to the opposite sides of the end of the cervix, and continuously displaying the spatial distance between them. The position of the fetal presenting part (e.g., fetal head) is also continuously indicated by continuously monitoring and displaying their respective locations

According to further features in the described preferred embodiments, the above conditions are computed and displayed in the form of units of distance (e.g., cm), and/or in the form of a graph, called a Partogram, showing the interrelation of the cervical dilatation and the descent of the fetal presenting part

According to a further aspect of the invention there is provided apparatus for monitoring the progress of labor in a mother during childbirth, comprising: a position sensor for attachment to a predetermined point on the mother's pelvic bones, and for producing an output signal identifying its location in space; means for sensing the location of the fetal presenting part with respect to the predetermined point on the mother's pelvic bones, and for producing an output signal identifying the location of the fetal presenting part; a computer connected to receive the output signals; and an output device controlled by the computer for outputting the position of the fetal presenting part with respect to the predetermined point of the mother's pelvic bones

The output device is preferably a display, but could be a plotter, recorder, or other device for displaying, recording, and/or processing the data outputted by the computer.

Another aspect of the present invention is a method of monitoring the progress of labor in a mother during childbirth, comprising: attaching a first sensor to a predetermined point on the mother's pelvic bones; monitoring the location of said first position sensor in three-dimensional space relative to a reference; attaching a second position sensor to the outer tip of the fetal resenting part; and monitoring the location of the fetal presenting part with respect to said predetermined point on the mother's pelvic bones to provide an indication of the progress of labor by monitoring the location of said second position sensor.

Another aspect of the present invention is an apparatus for monitoring the progress of labor, comprising; a first position sensor for attachment to a predetermined point on the mother's pelvic bones, and for producing an output signal identifying its location in space; means for sensing the location of the fetal presenting part with respect to said predetermined point on the mother's pelvic bones, and for producing an output signal identifying the location of said fetal presenting part, said means comprising a second position sensor for attachment to the outer tip of the fetal presenting part; a computer connected to receive said output signals; and an output device controlled by said computer for outputting the position of said fetal presenting part with respect to said predetermined point of the mother's pelvic bones.

As will be described more particularly below, such a method and apparatus permits the progress of labor to be monitored in a manner which is continuous rather than intermittent, which is less dependent for accuracy on the experience, judgment or finger size of the attendant in the conventional "finger examination", which subjects the mother to less discomfort, and which involves less risk of contamination, infection, dislodgment of a fetal monitor, or injury to or death of the baby or mother due to a wrong assessment of the fetal position or of labor progress. Moreover, this technique enables more precise monitoring of the critical condition, namely the changes in the spatial distance of the BPD of the baby's head with respect to the pelvic inlet.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a block diagram illustrating one form of system constructed in accordance with the present invention;

Fig. 2 illustrates one of the position sensors in the system of Fig. 1;

Fig. 3 is a block diagram of one type of position sensor system that may be used;

Fig. 4 more particularly illustrates the Partogram display in the system of Fig.1;

Fig. 5 is a block diagram illustrating an imaging system for displaying the image of the mother's womb, particularly the cervix, pelvic bones, and the fetal head to better show the progress of the labor;

Figs. 6A - 6D illustrates typical displays produced by the system of Fig. 5 during the various stages of labor;

Fig. 7 illustrates a typical display produced by the system of Fig. 5 during the descent of the fetal head;

Fig. 8 illustrates how the monitored data may be processed to display the changes in the spatial distance of the BPD of the baby's head with respect to the mother's pelvic inlet; and

Fig. 9 illustrates a fetal heart monitoring display and uterine contractions that may be included in the above-described systems of Fig. 1 or Fig. 5.

DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 schematically illustrates the mother's womb during labor, with the fetus 2 in its normal position within the uterus 3 wherein the fetal head 4 is downwardly oriented in preparation for delivery via the cervix 5 of the uterus. The cervix 5 is dilated and effaced in preparation for passage of the fetus via the cervical canal and the vaginal cavity. The various stages of descent of the fetal head during delivery may be measured in relation to the ischial spines or the pelvic inlet 8a of the pelvic bones 8.

The progress of labor is monitored by a plurality of position sensors attached to the fetal head and to the varous parts of the mother's womb and pelvis, as follows: a first position sensor PS_1, is attached to one of the pelvic bones 8 at a known distance from the ischial spines and the pelvic inlet 8a; a second postion sensor PS_2 is attached to the fetal head 4 (or other presenting part of the unborn baby if not the fetal head); and third and fourth position sensors PS_3, PS_4 are attached to the opposite sides of the external opening of the uterine cervix 5.

The first position sensor PS_1, is attached to one of the pelvic bones 8 in a manner permitting the computer to map the pelvis and to track its movements, particularly the pelvic inlet. Following is a procedure which may be used for this purpose:

(a) the mother is instructed not to move;

(b) PS_1 is attached to one known point of the pelvis, (e.g., the left anterior superior spine (the highest bone point on the left side at the waist level), and is used to identify this point to the computer;

(c) PS_1 is attached to a second known point, e.g. the central point of the symphys pubis (the pelvic bone at the front of the body), and this point is also identified to the computer;

(d) PS_1 is attached to a third point, e.g., the right anterior superior spine, and this point is also identified to the computer;

(e) based on the above three points, the computer can now compute the entire spatial position of the pelvis; and

(f) PS_1 is finally firmly attached to the last (third) point so that it does not move nor rotate relative to the pelvic bone henceforth.

The computer can now track every movement of the pelvis, and thus can continuously monitor the spatial position of the entire pelvis, particularly the pelvic inlet.

Each of the position sensors PS_1- PS_4 is fixed in any suitable manner (e.g., by stitches, clips, suction cups, etc.) to its respective surface. Each is capable of sensing its precise position and orientation in three-dimensional space with respect to a reference. The position sensor may also be carried at one end of a rigid rod or other support which is clipped at its other end to the respective surface.

Many types of position sensors are known for this purpose. In the illustrated example, position sensors PS_1 - PS_4 are of the magnetic field type as described for example in Blood US Patent 4,945,305. They output signals, when triggered by a transmitter 10, enabling the precise position of the sensor to be computed by a computer 12 connected to receive the outputs of the position sensors as well as the signals transmitted by the transmitter 10. Computer 12 computes the precise position and orientation of each sensor PS_1 - PS_4, and from these computations, controls displays as shown at 14 and 16, for displaying various physiological conditions of the mother and baby during labor, particularly the following:

1. Effacement: This is the process of thinning out the cervix that takes place before and during the first stage of labor. The cervix is thinned by retraction in order to allow more room for the birth process. Effacement is expressed in percent, from zero percent (uneffaced) to one hundred perçent (cervix less than about 0.25 cm thick). In the system illustrated in Fig. 1, effacement is computed and displayed at 14a as the spatial distance between position sensor PS_2 attached to the fetal head and the middle point on the line connecting the two position sensors PS_3, PS_4 attached to the ends of the uterine cervix 5.

2. Cervical dilatation: This is the enlargement of the cervical opening. It is considered to be fully dilated when its diameter measures 10 cm since the fetal head of a term-sized infant usually can pass throught a cervical opening of that diameter. In the system illustrated in Fig. 1, the cervical dilatation is computed and displayed at 14b as the spatial distance between the two position sensors PS_3, PS_4, attached to the opposite sides of the uterine cervix 5.

3. Position of the cervix: This is the forward-backward inclination of the cervix. In this case it is measured as the orientation of the central axis of the cervix, which is the line connecting the position sensor PS_2, attached to the presenting part of the fetus, and the middle point on the line connecting the two position sensors PS_3, PS_4 attached to the opposite sides of the cervix. An initial

orientation of that cervical axis is taken at the beginning of labor, and the progress of the cervical position is indicated as the relative angle between the cervical axis at any given time to the angle of initial orientation. The physician may designate any angular range as either "forward", or "middle", or "backward".

Alternatively, the cervical position may be indicated as the distance between the symphys pubis, as determined by position sensor PS_1, and the middle point of the line connecting the two position sensors PS_3, PS4 attached to the opposite sides of the cervix.

4. Station: This is the position of the fetal head (or other presenting part) with respect to a predetermined point of the mother's pelvis. As indicated earlier, the conventional station is the distance between the tip of the fetal head and the ischial spines; but a more accurate way of measuring the station would be to measure the distance between the BPD and the pelvic inlet. In the system illustrated in Fig. 1, the station may be computed and displayed in the conventional manner, based on the distance between the tip of the fetal head and the ischial spines as illustrated in Fig. 7, or in the more accurate manner based on the spatial distance of the BPD to the pelvic inlet as illustrated in Fig. 8.

As indicated earlier, the position sensors PS_1 - PS_4 may be of any known type. Fig. 2 schematically illustrates one of such position sensors PS. It includes a triangular array of three spaced-apart magnetic coils 21, 22, 23, all at precisely known distances from the center point 24 of the position sensor. Thus, by determining the positions and orientations of the three coils 21-23 with respect to a reference, the precise location of the center point 24 of the position sensor PS can be determined with respect to that reference.

An example of a position sensor system which could be used is that described in Blood US Patent 4,945,305. Such a system, illustrated in the block diagram of Fig. 3, is capable of precisely measuring the position (location and orientation) in six degrees of freedom of receiving antenna 30 with respect to transmitting antenna 31 utilizing pulsed DC magnetic signals. The transmitting and receiving components consist of two or more transmitting antennas of known locations and orientation with respect to each other. The transmitting antennas 31 are driven one at a time (by a pulsed, direct current signal) from a DC drive circuit 32. The receiving antenna 30 measures the transmitted direct current magnetic fields and the earth magnetic field in a signal processing circuit 33 and feeds this information to a computer 34 which thereby determines the position of the receiver antenna 30.

Further details of the construction and operation of such a position sensor system are set forth in US Patent 4,945,305. Other magnetic field systems which could be used would be one based on AC fields, such as described in the patents set forth in the discussion of the prior art in the Blood patent.

Other position sensing systems that could be used for the position sensors $PS_1 - PS_4$ are those produced by Polhemus Inc. or by Ascension Technology Corporation, both of Burlington, VT, USA. In such systems, three mutually perpendicular magnetic fields are transmitted in sequence, and three mutually perpendicular directional coils are employed to detect the several magnetic fields. A computer is employed to compute the spatial position and orientation of the combined coils.

A still further position sensing system that could be used is that produced by Adaptive Optics Associates, Inc., of Cambridge, MA, USA. This one includes multiple light sources attached to the object whose position and orientation is to be detected, and a multiplicity of cameras positioned in known spatial locations to detect the light emitted by the light sources. A computer combines all the data and computes the position and orientation of the object.

Yet another position sensor system that could be used is that of Science Accessories Corporation of Newhaven, CT, USA. It includes an ultrasound source attached to the point on the object whose position is to be detected, and a multiplicity of microphones positioned in known spatial locations to detect the sound emitted by the ultrasound source. A computer combines the data and computes the position of the object. By attaching multiple spaced-apart ultrasound emitters of the object, its orientation can also be computed by combining the position data of each of the emitters.

Preferably, the position sensors are of the wireless type so as to minimize interference with the birth process. However, in some cases it may be advantageous to use a mechanical positioning system based on robotic arms physically connected to the tracked objects and equipped with mechanical sensors at the joints (rotary encoders) which enable precise spatial location of the tracked objects.

Computer 12 (Fig. 1) which receives data corresponding to the positions of the position sensors PS_1 - PS_4, processes this data to provide the type of display that may be desired. Fig. 1 illustrates two types of displays 14, 16. Display 14 displays each parameter, effacement, cervical dilation, cervix position, station and/or BPP distance, in the form of units of distance (e.g. cm). Display 16, however, is a Partogram, in which the cervical dilatation and the station are displayed in graphical form as a function of time to show the interrelation of the cervical dilatation and the descent of the fetal head (or other presenting part) and in which the effacement and cervical position may also be similarly displayed.

The Partogram display 16, which is more particularly illustrated in Fig. 4, is of special value since it provides a visual display of the progress of labor and can be recorded if desired. By using the Partogram, a better determination can be made whether labor is progressing normally. "Alert" and "action" lines may be printed on the Partogram to provide a visible indication of whether labor is progressing normally or abnormally, and thereby to better alert the attending personnel to take prompt action if necessary. Such an "electronic Partogram" can also markedly reduce the number of prolonged labors, the rate of intrapartum, post partum and early neonatal infections, the number of unnecessary interventions, and neonatal trauma due to wrong assessment of the fetal head.

Fig. 5 illustrates a monitoring system similar to that of Fig. 1 but further equipped with an imaging system for imaging the womb area of the mother and for continuously displaying the mother's cervix, pelvic bones, and fetal head (or other presenting part).

Thus, Fig. 5 includes an ultrasonic transducer 40 for imaging the womb area, via the computer 12, on an image display 42. It also includes a position sensor PS5 attached to the ultrasonic transducer 40. Thus, any point in the image on display 42 may be selected by a marker device 43, such as a mouse or touch screen, and its location fed into the computer 12 to identify the location of the respective point with respect to the location of position sensor PS1 attached to the mother's pubic bones. With this information, the computer 12 can compute the various relationships displayed in displays 14 and 16, thereby obviating the need for the positions sensors PS2, PS3 and PS4. The image displayed in display 42 may be used in the same manner for marking the BPD on the fetal head as illustrated in Fig. 8, thereby enabling particularly the spatial distance between the fetal BPD and the pelvic inlet to be computed and monitored.

It will be appreciated that other reference points, other than the BPD or the tip of the fetus head, as well as any other point of the mother's pelvis, may be used as the reference points for monitoring the progress of the labor. This freedom is important because of the variety of preferences among various physicians.

The imaging system illustrated in Fig. 5 could also be used to provide a visual image of the various stages of labor, e.g., as illustrated in Figs. 6A - 6D showing the progressive dilatation and effacement of the cervix, or as illustrated in Figs. 7 and 8 showing the progressive descent of the fetal head tip through the various stations with respect to the ischial spines 7 (Fig. 7) or mother's pelvic inlet (Fig. 8).

If the imaging system is used together with all five position sensors PS1-PS5 illustrated in Fig. 5, the ultrasound imaging may be used only to measure the BPD at the beginning of labor or later. The computer then determines the distance between the BPD and the tip of the fetal head, and thereafter it can use the position of the tip of the fetal head also to determine the

BPD position. The ultrasound imaging may thereafter be used only for verification if desired. It can also be used to verify cervical dilatation and effacement.

If the system illustrated in Fig. 5 is used with only the ultrasound imaging and position sensors PS1 and PS5, the monitoring would preferably not be continuous but only intermittent, i.e., only when it is desired to monitor a specific stage in the progress of the labor.

The system illustrated in Fig. 5 may also be used for sensing contractions in the mother's uterus. Thus, during contractions, the fetal head moves slightly, and the dilatation also grows slightly; and after contractions, they both retract to their previous positions. By thus observing the dilatation and/or fetal head position as a function of time, the attending physician may discern the occurrence of contractions as well as the duration and strength of such contractions. In addition, by including a heart pulse sensor in the fetal head position sensor PS2, the physician may observe the relation of the fetal heart rate (FHR) in relation to the uterine contractions (UC), to show the relationship between the two as illustrated in Fig. 9. Computer 12 may be programmed to receive the above information from the various sensors and produce, in a monitor 45, a display corresponding to the fetal heart rate (FHR) in relation to the uterine contractions (UC), as illustrated in Fig. 9. Such information is particularly desirable if the presence of complications is established or anticipated.

While separate displays are shown in the drawings, it will be appreciated that these displays could be in the form of windows on the same large computer display.

While the invention has been described with respect to several preferred embodiment, it will be appreciated that these are set forth merely for purposes of example, and that many other variations, modifications and applications of the invention may be made.

CLAIMS

1. A method of monitoring the progress of labor in a mother during childbirth using a system comprising a first position sensor attached to a predetermined point in the mother's pelvic bones and a second position sensor attached to the outer tip of the fetal presenting part; said method comprising: monitoring the location of said first position sensor in three-dimensional space relative to a reference; and monitoring the location of the fetal presenting part with respect to said predetermined point on the mother's pelvic bones to provide an indication of the progress of labor by monitoring the location of said second position sensor.

2. The method according to Claim 1, further comprising monitoring the location of the opposite sides of the end of the mother's uterine cervix with reference to each other to provide an indication of the dilatation of the mother's cervix.

3. The method according to Claim 2, further comprising monitoring the location of the opposite sides of the end of the mother's uterine cervix with reference to the fetal presenting part and the mother's pelvic bones to provide an indication of the cervical position of the mother.

4. The method according to Claim 1, wherein the locations of said opposite sides of the mother's uterine cervix are monitored by

attaching third and fourth position sensors to them, and monitoring their respective locations.

5. The method according to Claim 4, wherein the station of the fetal presenting part is continuously indicated by continuously monitoring the positions of said first and second position sensors, and continuously displaying the spatial distance between them.

6. The method according to Claim 5, wherein the cervical dilatation of the mother's cervix is continuously indicated by continuously monitoring the positions of said third and fourth position sensors and continuously displaying the spatial distance between them.

7. The method according to Claim 6, wherein said cervical dilatation and said station are computed and displayed in centimeters.

8. The method according to Claim 6, wherein said cervical dilatation and said station are computed and displayed in the form of a Partogram showing the interrelation of the cervical dilatation and the descent of the fetal presenting part.

9. The method according to any one of Claims 4-8, wherein effacement of the mother's cervix is continuously indicated by continuously monitoring and displaying the spatial distance of said second position sensor from said third and fourth position sensors.

10. The method according to any one of Claims 4-9, wherein the position of the mother's cervix is continuously indicated by continuously

monitoring and displaying the spatial distances between said first, second, third and fourth position sensors.

11. The method according to Claim 10, wherein said effacement and position of the mother's cervix are computed and displayed in centimeters.

12. The method according to any one of Claims 4-9, wherein the position of the mother's cervix is continuously indicated by continuously monitoring and displaying the angle of the cervical axis as indicated by said second, third and fourth position sensors.

13. The method according to Claim 1, wherein the location of said fetal presenting part is monitored by attaching the second position sensor to an ultrasonic transducer, operating said ultrasonic transducer to image said fetal presenting part on a screen, monitoring the location of said second position sensor and thereby the location of said ultrasonic transducer to which it is attached, and determining the location of the fetal presenting part as imaged on said screen.

14. The method according to Claim 13, wherein the monitored locations of the first position sensor and of the fetal presenting part are processed to provide an indication of the spatial distance of the bi-parietal diameter (BPD) of the fetal presenting part with respect to the mother's pelvic inlet.

15. The method according to any one of Claims 1-14, wherein, before attaching the first position sensor to a predetermined point on the mother's pelvic bones and monitoring its location, the entire spatial position of the mother's pelvis is mapped.

16. The method according to Claim 15, wherein the mother's pelvis is mapped by:

attaching a pelvic position sensor to one known point of the pelvis and outputting an electrical signal identifying the location of said one point;

attaching the pelvic position sensor to a second known point of the pelvis and outputting an electrical signal identifying the location of said second point;

attaching the pelvic position sensor to third known point of the pelvis and outputting an electrical signal identifying the location of said third point; and

processing said first, second and third electrical signals to compute the entire spatial position of the pelvis.

17. The method according to Claim 16, wherein said first point is the left anterior superior spine; said second point is the central point of the symphys pubis; and said third point is the right anterior superior spine.

18. The method according to either of Claims 16 or 17, wherein, after the entire spatial position of the pelvis is mapped, said pelvic position sensor at said third point is left attached to said third point while its location is monitored during the mother's labor.

19. The method according to any one of Claims 4-18, wherein contractions in the mother's uterine cervix are sensed, and the fetal heart rate is sensed and is displayed in relation to the uterine contractions.

20. The method according to Claim 19, wherein said contractions in the mother's uterine cervix are sensed by monitoring said second, third and fourth position sensors to indicate the variations in the position of the fetal presenting part and of the cervix.

21. Apparatus for monitoring the progress of labor, comprising;

a first position sensor for attachment to a predetermined point on the mother's pelvic bones, and for producing an output signal identifying its location in space;

means for sensing the location of the fetal presenting part with respect to said predetermined point on the mother's pelvic bones, and for producing an output signal identifying the location of said fetal presenting part, said means comprising a second position sensor for attachment to the outer tip of the fetal presenting part;

a computer connected to receive said output signals; and an output device controlled by said computer for outputting the position of said fetal presenting part with respect to said predetermined point of the mother's pelvic bones.

22. The apparatus according to Claim 21, further comprising means for sensing the locations of the opposite sides of the mother's uterine cervix with reference to each other to produce output signals which are received by said computer and processed to control said output device for outputting an indication of the dilatation of the mother's cervix.

23. The apparatus according to Claim 22, further comprising means for sensing the locations of the opposite sides of the mother's uterine cervix with reference to the fetal presenting part and the mother's pelvic bones to produce output signals which are received by said

computer and processed to control said output device for outputting an indication of the cervical position of the mother.

24. The apparatus according to Claim 21, wherein said means for sensing the locations of the opposite sides of the mother's uterine cervix include third and fourth position sensors for attachment to the opposite sides of the mother's uterine cervix and for producing output signals to the computer identifying their respective locations.

25. The apparatus according to Claim 24, wherein said computer computes, and said output device displays, the station of the fetal presenting part as the spatial distance between said first and second position sensors.

26. The apparatus according to Claim 25, wherein said computer computes and said output device displays, the cervical dilatation of the mother's cervix as the spatial distance between said third and fourth position sensors.

27. The apparatus according to Claim 26, wherein said computer computes, and said output device displays, said cervical dilatation and said station in centimeters.

28. The apparatus according to Claim 26, wherein said computer computes, and said output device displays, said cervical dilatation and said station in the form of a Partogram showing the interrelation of the cervical dilatation and the descent of the fetal presenting part.

29. The apparatus according to any one of Claims 24-28, wherein said computer computes, and said output device displays, the effacement of the mother's cavity as the spatial distance of said second position sensor from said third and fourth position sensors.

30. The apparatus according to any one of Claims 24-29, wherein said computer computes, and said output device displays, the position of the mother's cervix as the spatial distances between said first, second, third and fourth position sensors.

31. The apparatus according to Claim 30,wherein said effacement and position of the mother's cervix are computed and displayed in centimetres.

32. The apparatus according to any one of Claims 24-29, wherein said computer computes, and said output device displays, the angle of the cervical axis as indicated by said second, third and fourth position sensors.

33. The apparatus according to either of Claims 22 or 23, wherein said means for sensing the locations of the fetal presenting part and of the opposite sides of the mother's cerrvix comprises:

an ultrasonic transducer to image said fetal presenting part and uterine cervix on a screen; and

a marker for marking a selected point of the fetal presenting part, and the opposite sides of the mother's uterine cervix, as imaged on the screen, and for outputting electrical signal identifying their respective locations to the computer; and

the second position sensor is attached to said ultrasonic transducer.

34. The apparatus according to Claim 33, wherein when said marker marks the bi-parietal diameter (BPD) of the fetal presenting part as imaged on the screen, said computer computes the distance between said BPD and the mother's pelvic inlet.

35. The use of the apparatus of any one of claims 21 to 34 for monitoring the progress of labor in a mother during childbirth.

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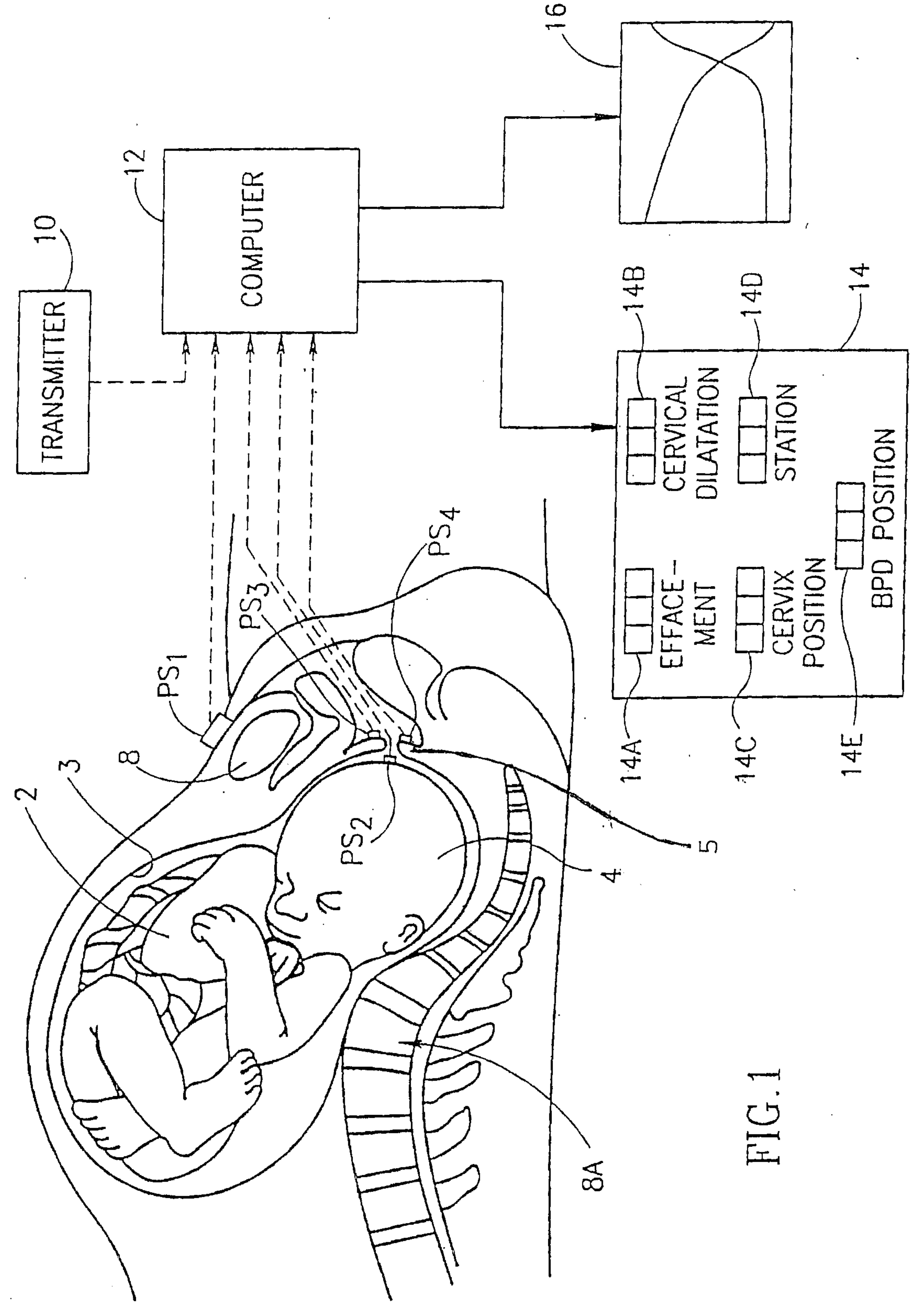

TRANSMITTER
10
COMPUTER
12
16
14B
CERVICAL DILATATION
14D
STATION
14
EFFACE- MENT
CERVIX POSITION
BPD POSITION
14A
14C
14E
PS1
PS2
PS3
PS4
2
3
4
5
8
8A

FIG.1

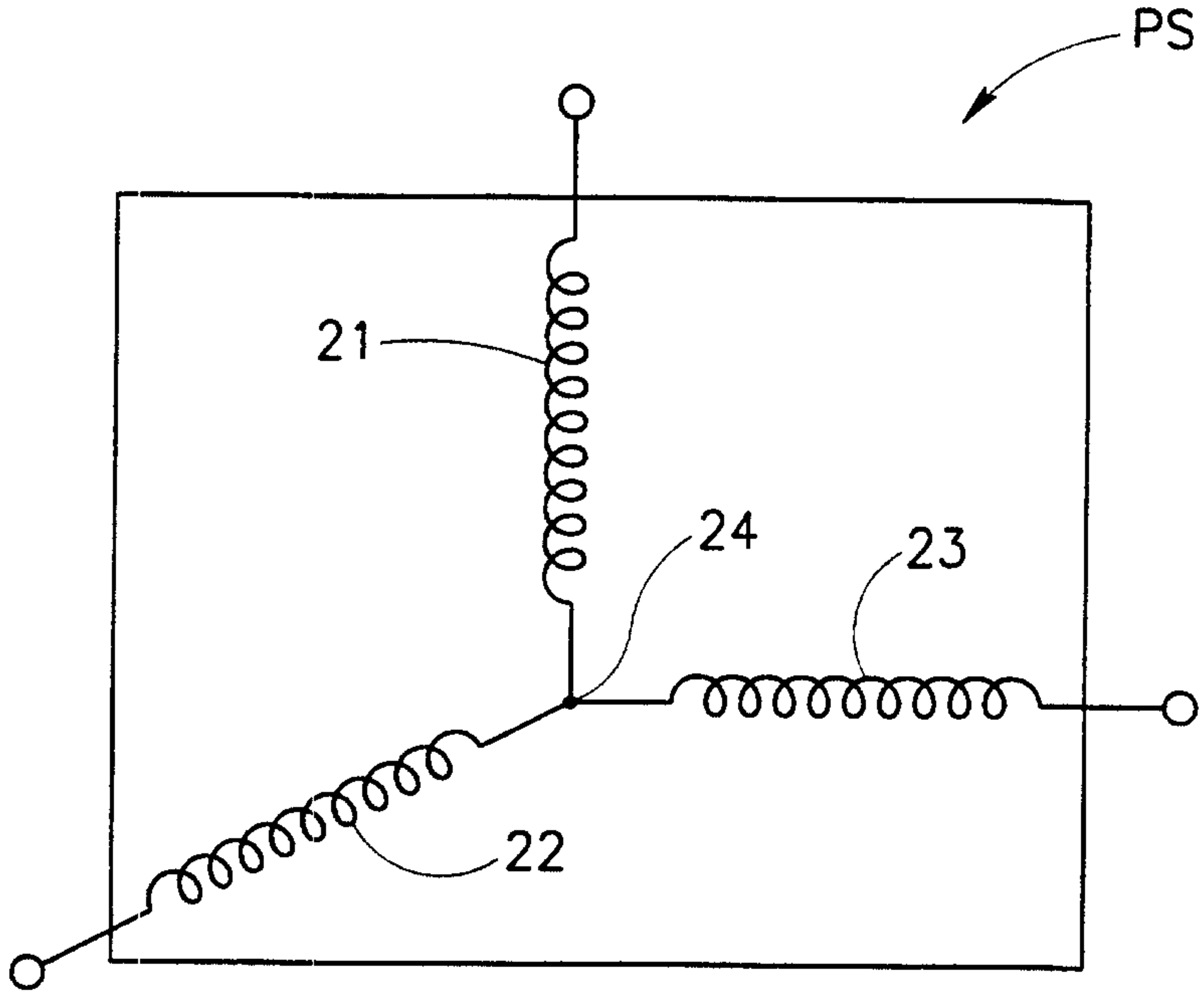

PS
21
24
23
22

FIG.2

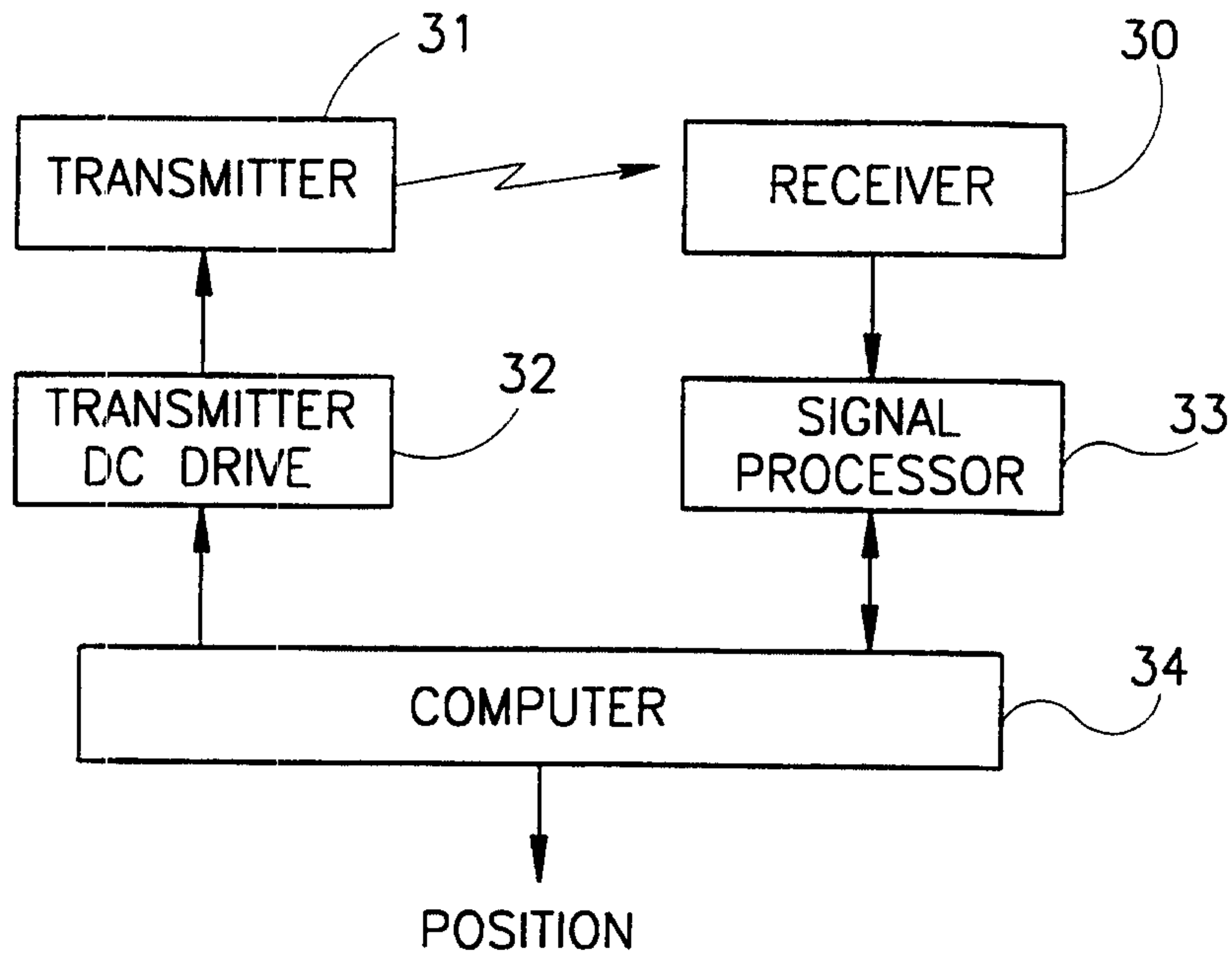

31
30
TRANSMITTER
RECEIVER
32
TRANSMITTER
DC DRIVE
SIGNAL
PROCESSOR
33
34
COMPUTER
POSITION

FIG.3

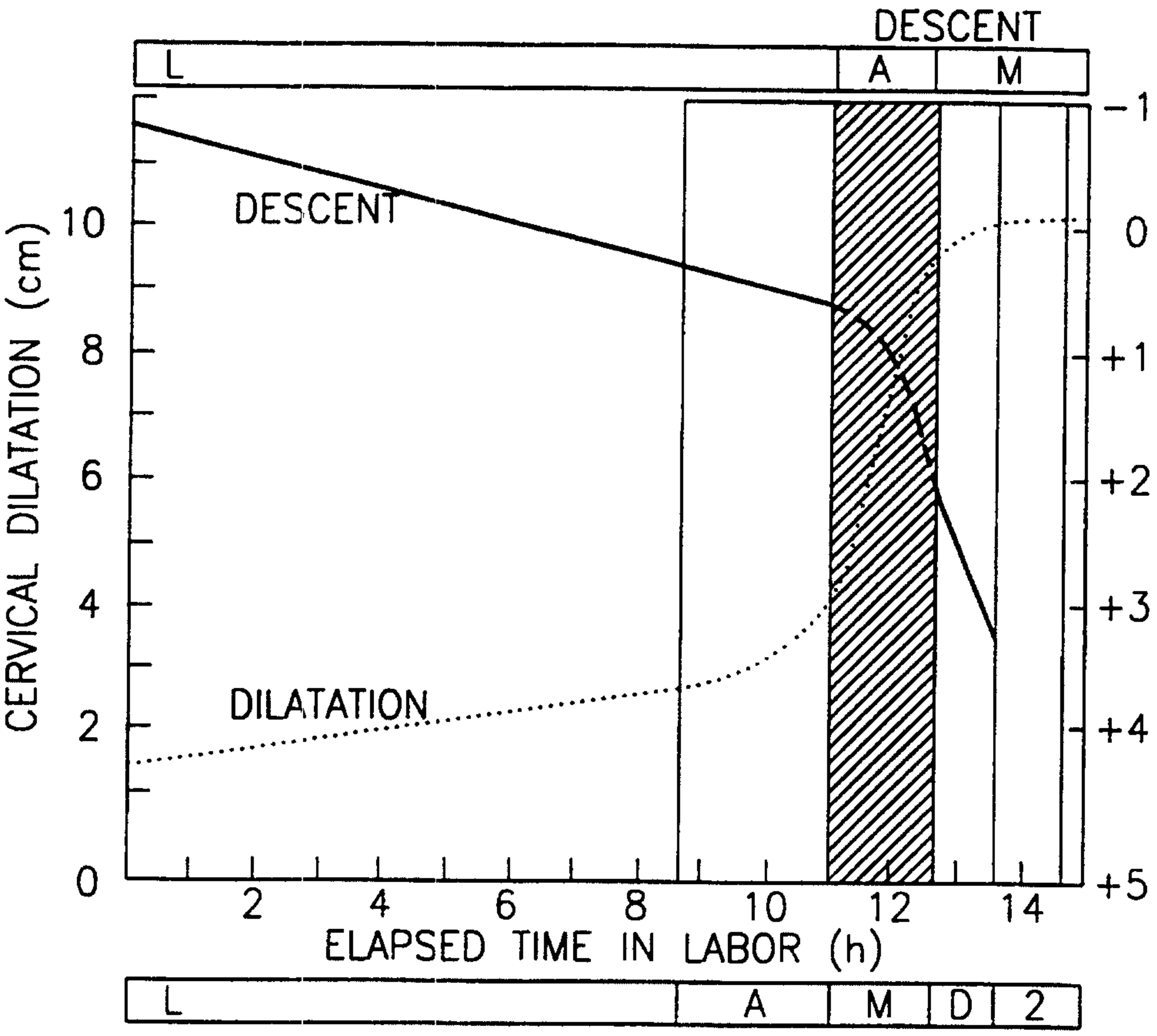

DESCENT
L
A
M
DESCENT
DILATATION
CERVICAL DILATATION (cm)
0
2
4
6
8
10
12
14
ELAPSED TIME IN LABOR (h)
-1
0
+1
+2
+3
+4
+5
STATION (cm)
L
A
M
D
2

FIG.4

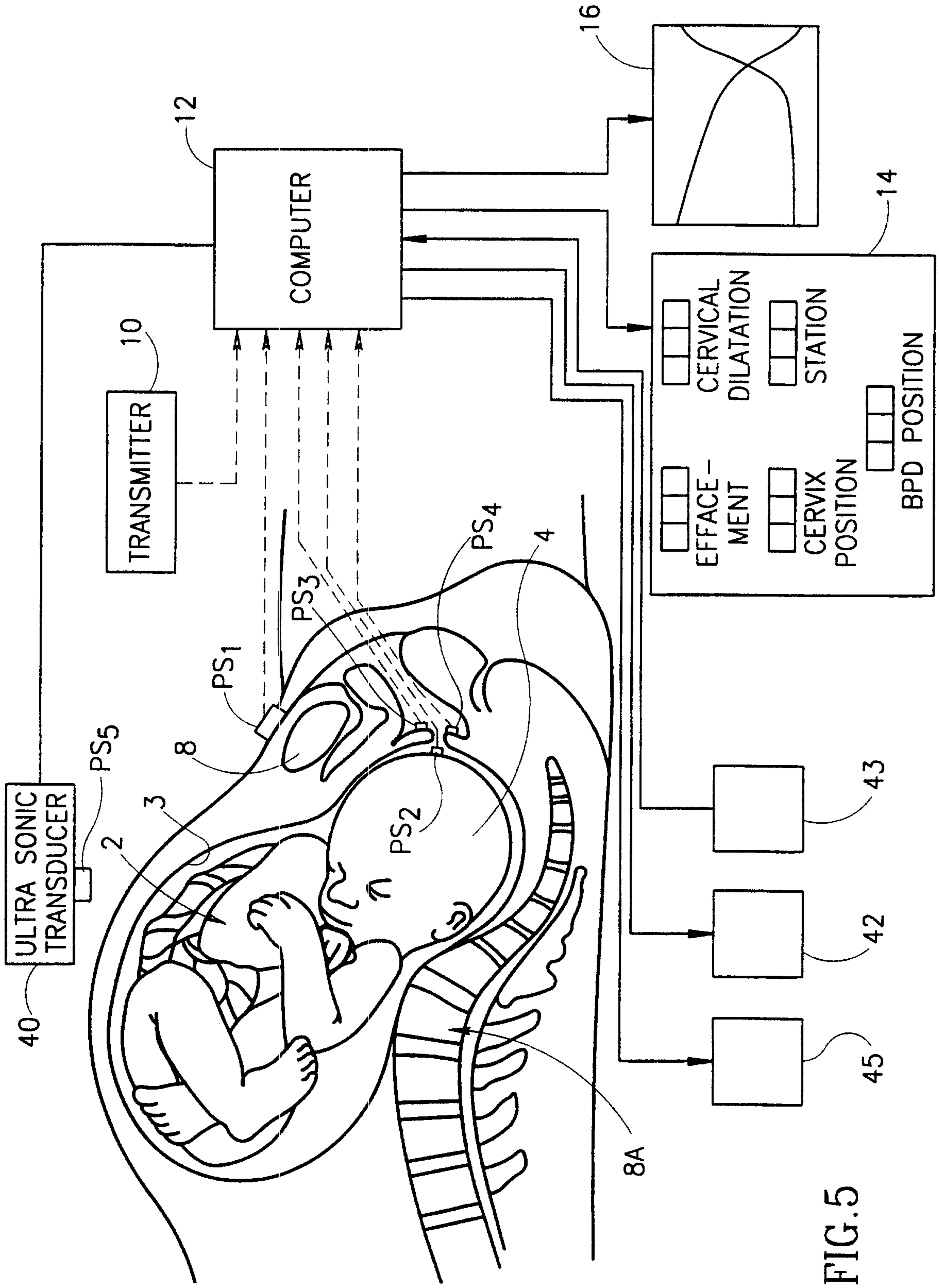

COMPUTER
12
16
14
TRANSMITTER
10
CERVICAL DILATATION
STATION
EFFACE- MENT
CERVIX POSITION
BPD POSITION
ULTRA SONIC TRANSDUCER
40
PS5
PS1
PS2
PS3
PS4
8
3
2
4
8A
43
42
45

FIG.5

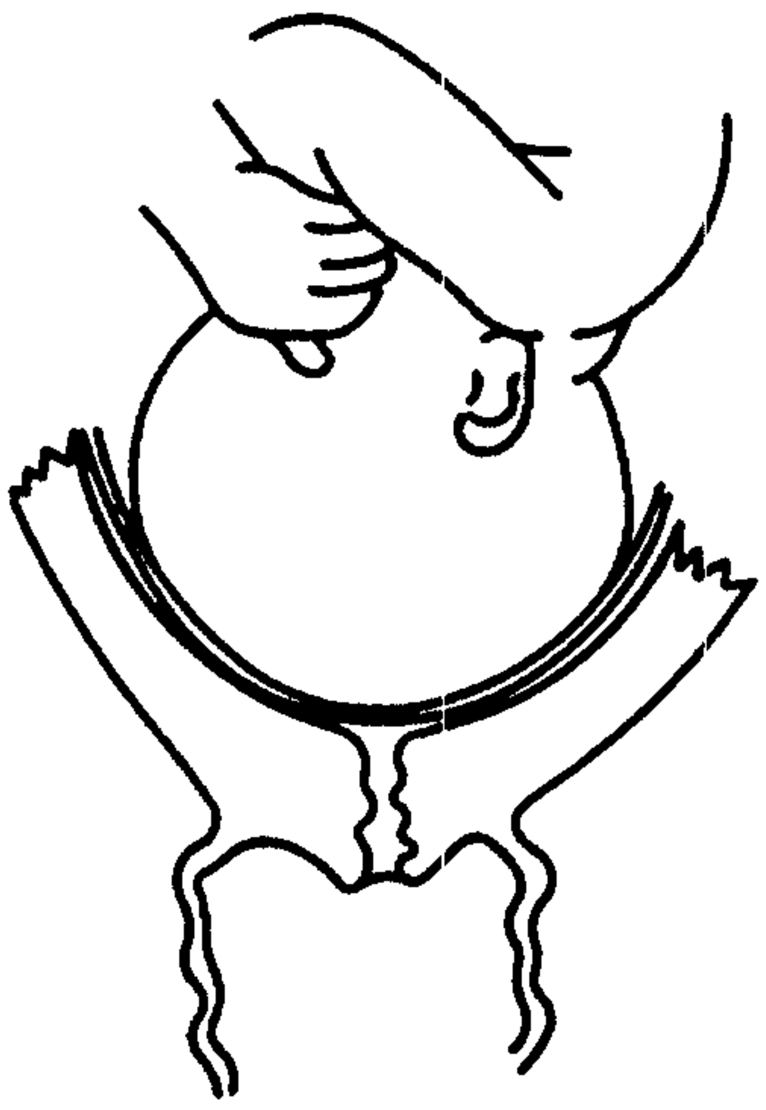


FIG.6A

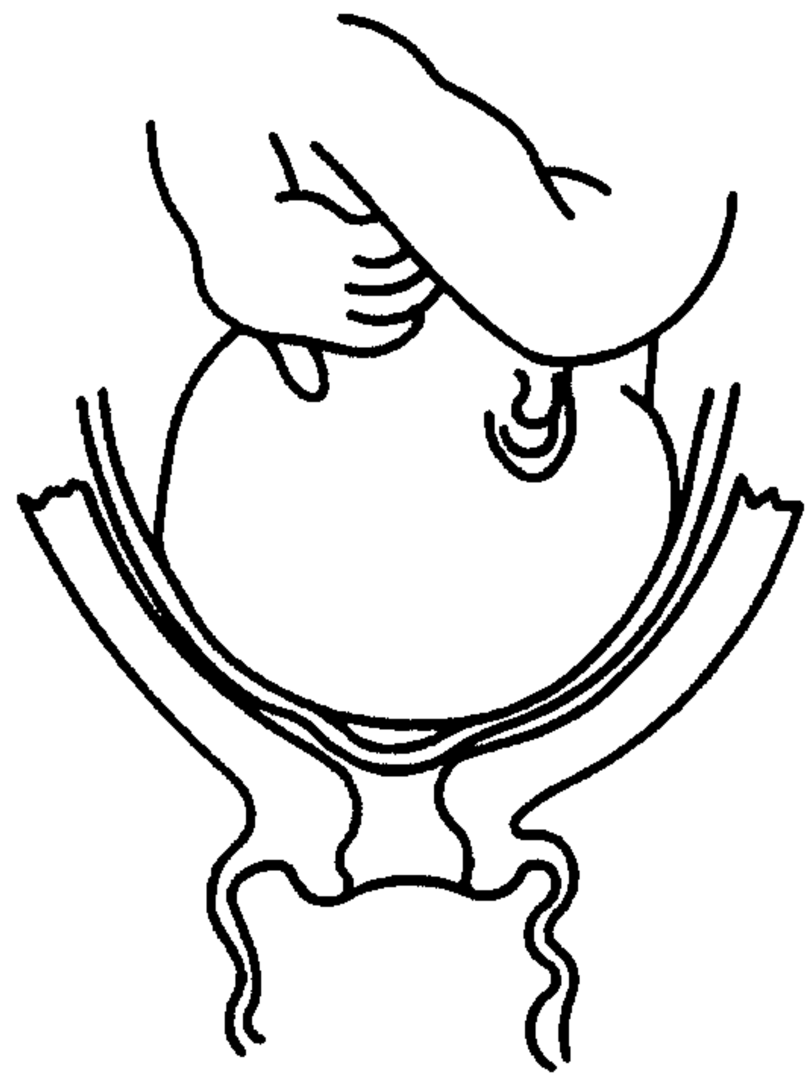


FIG.6B

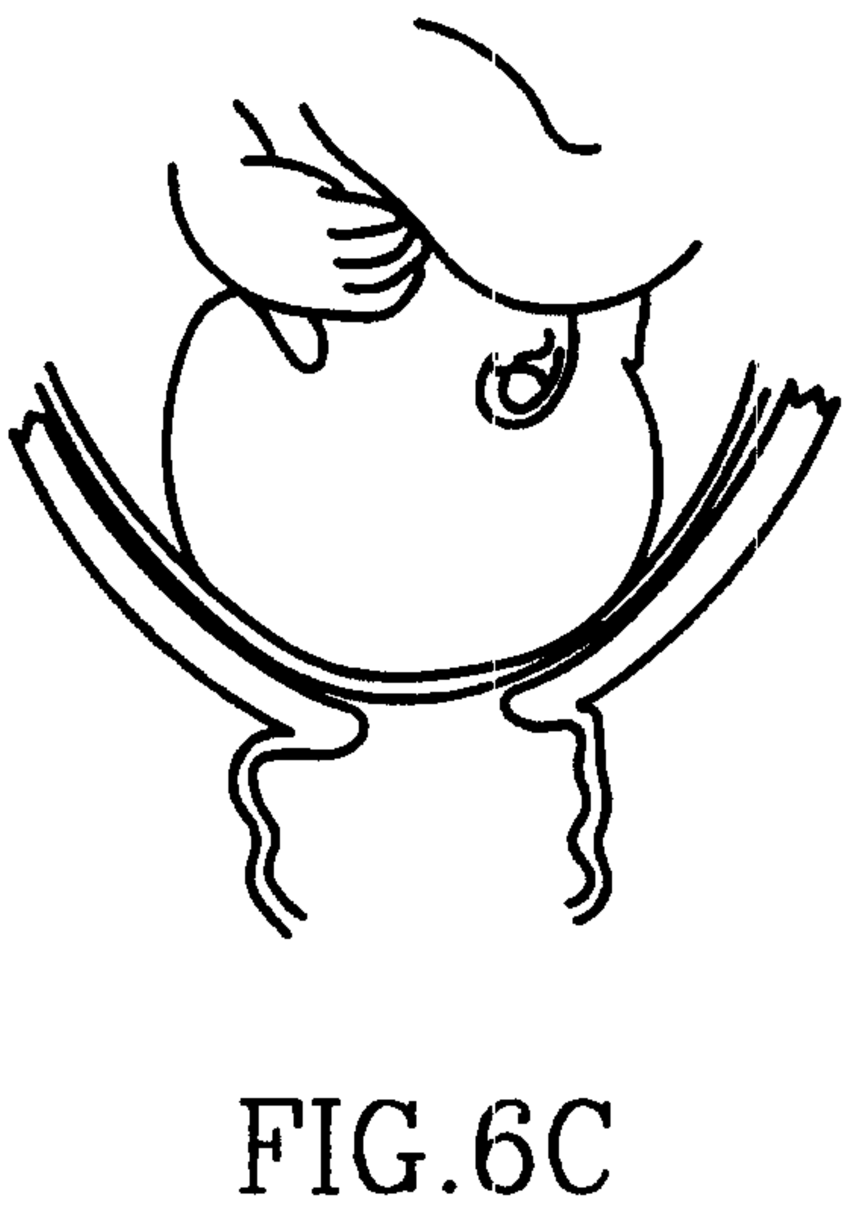


FIG.6C

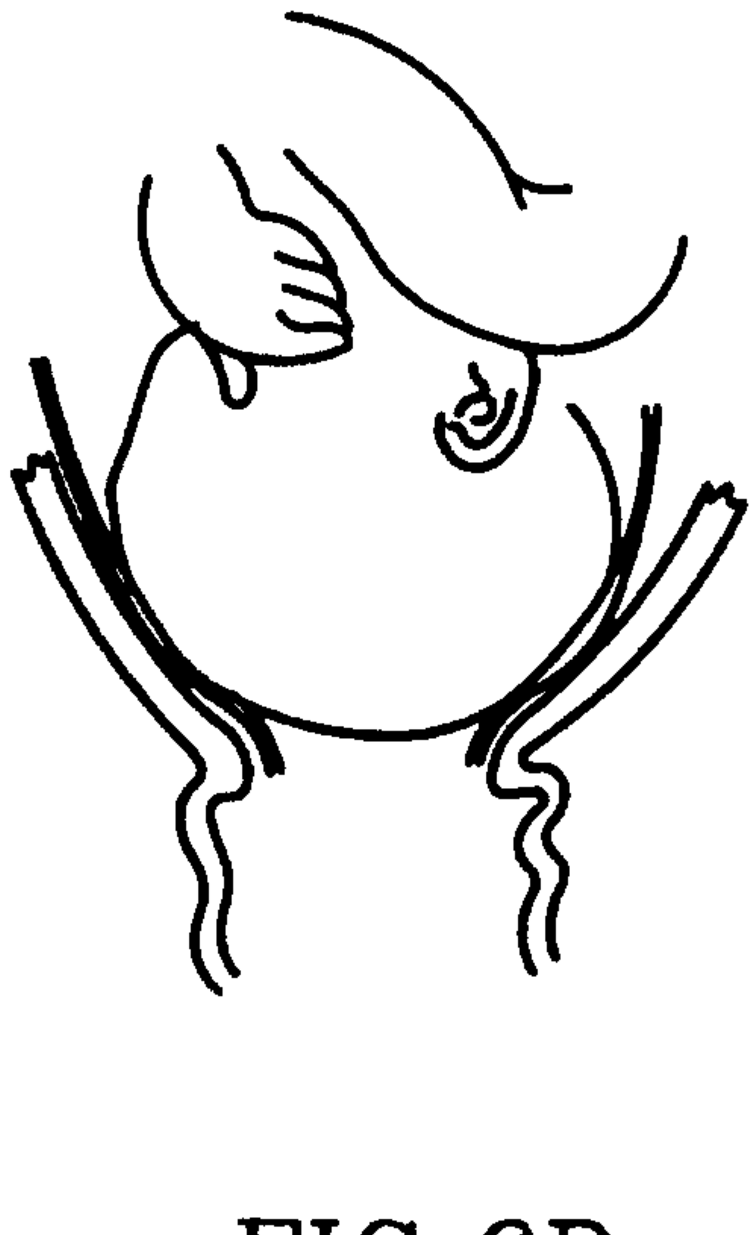


FIG.6D

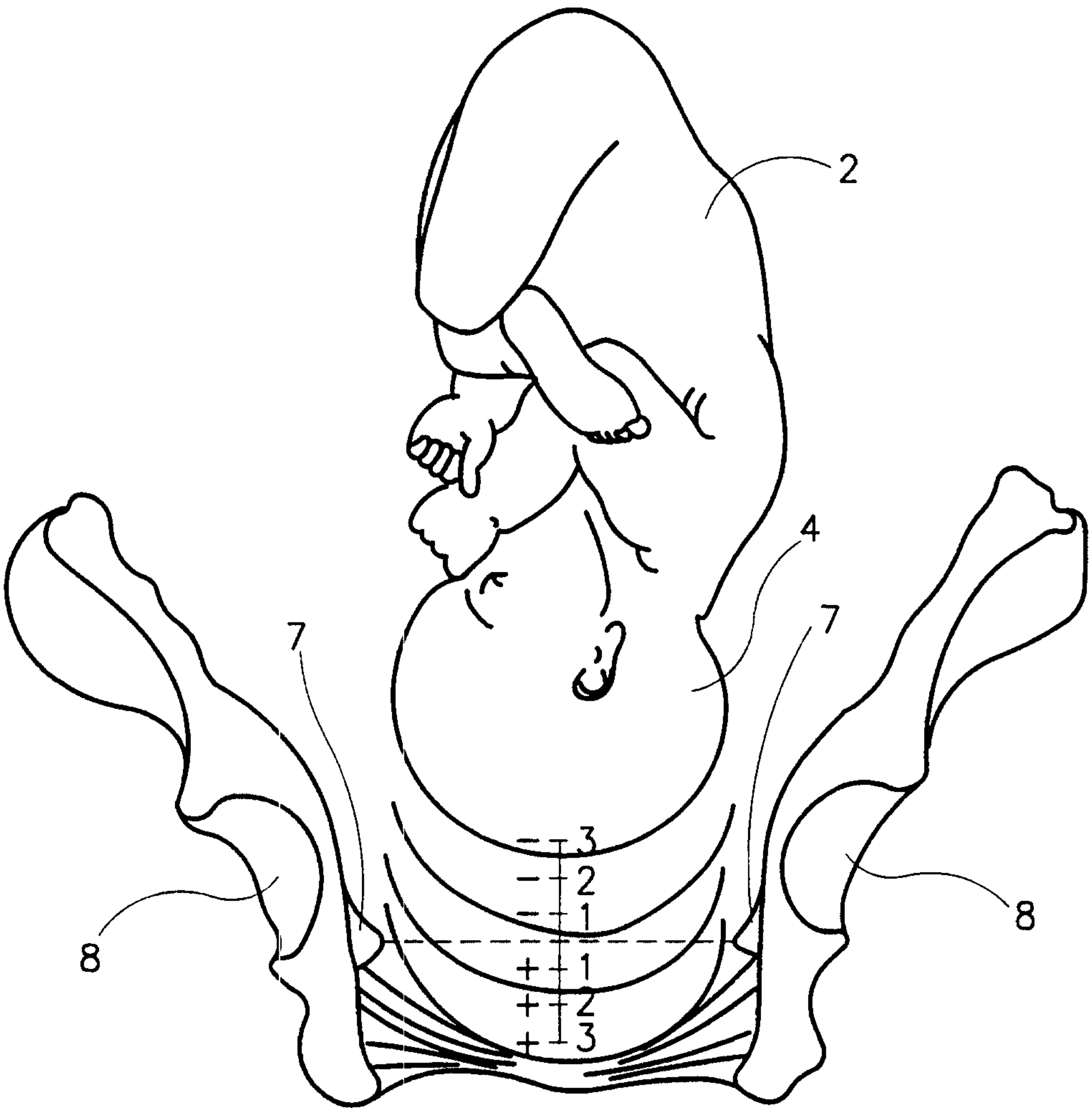


FIG.7

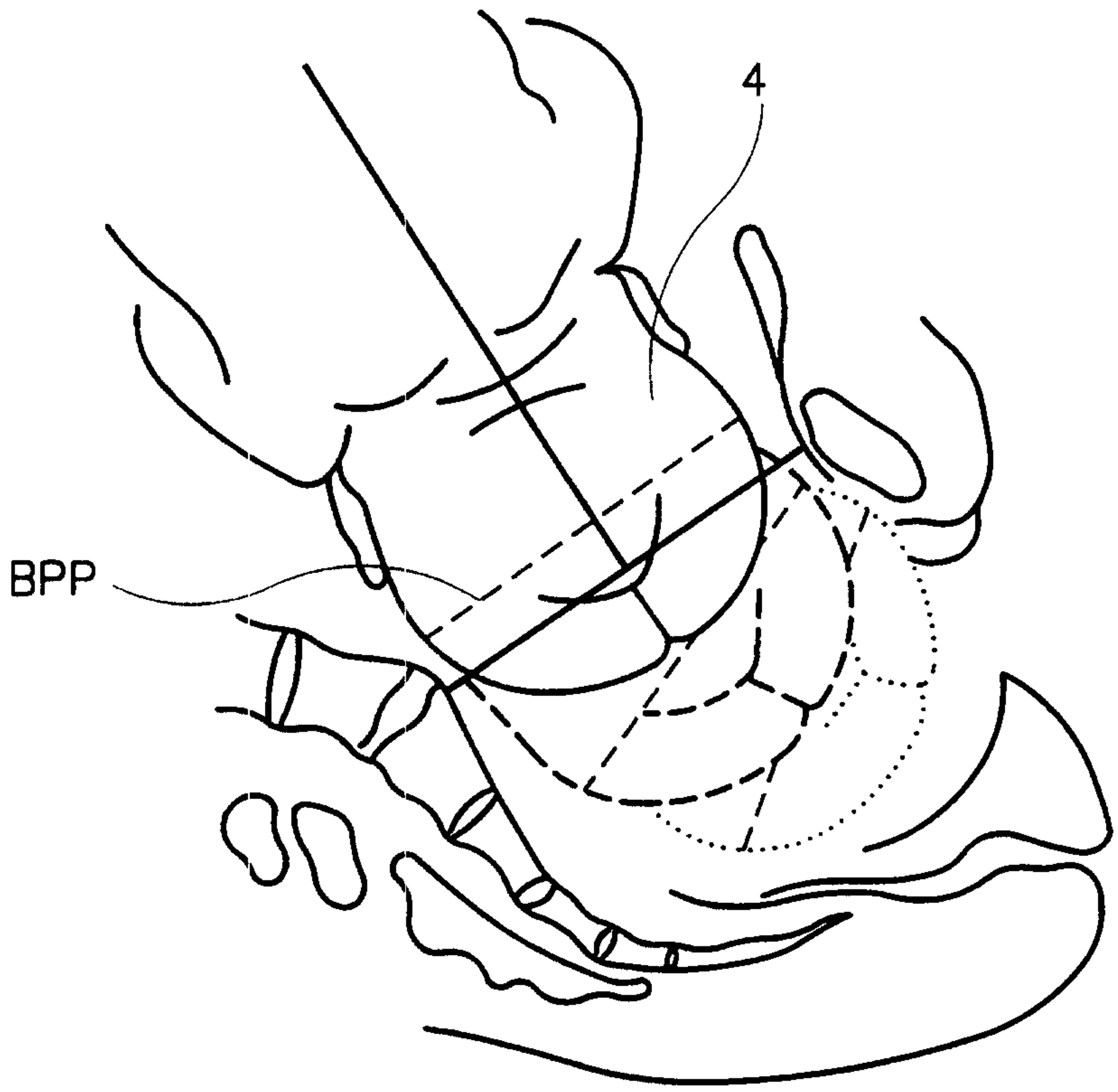


FIG.8

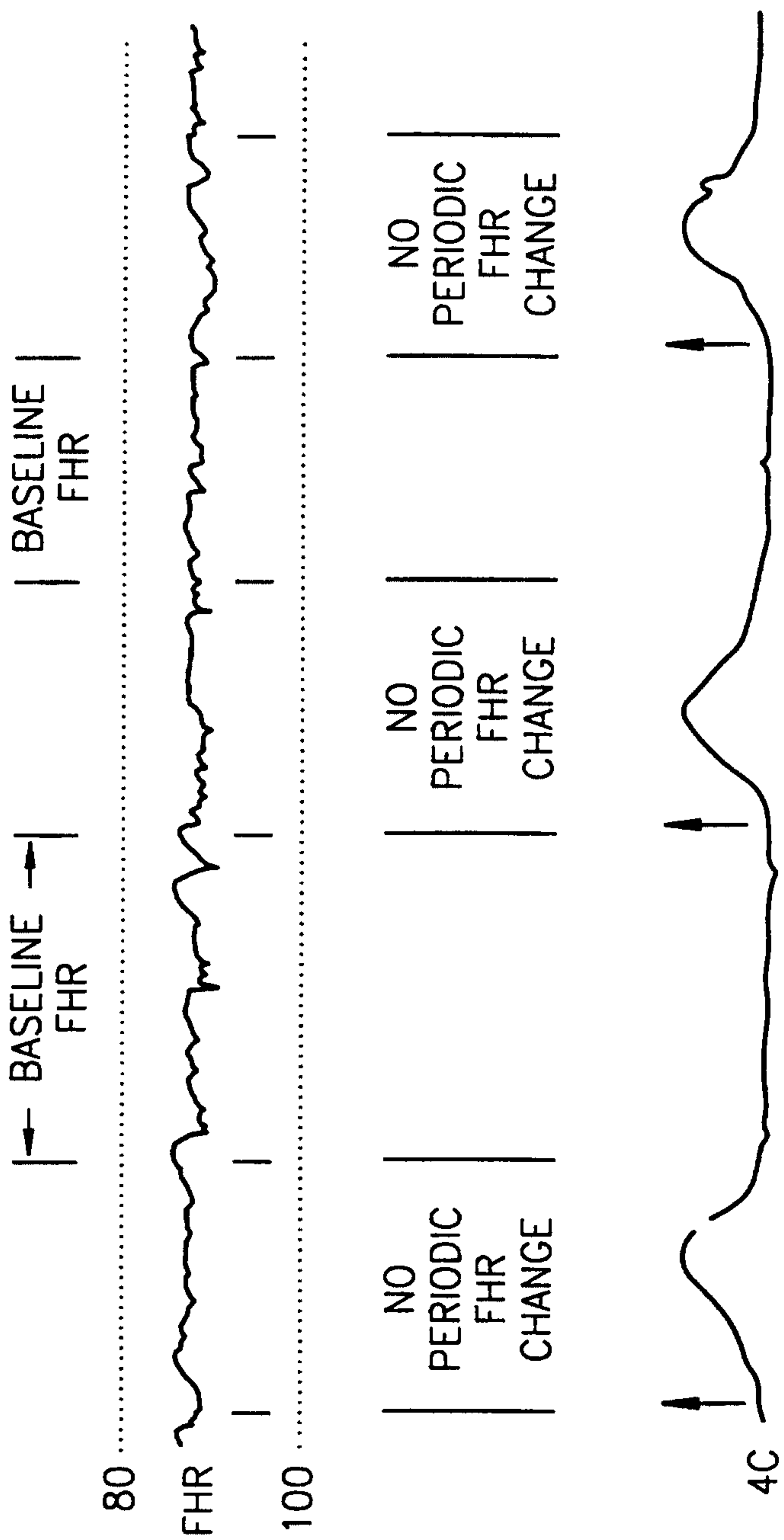
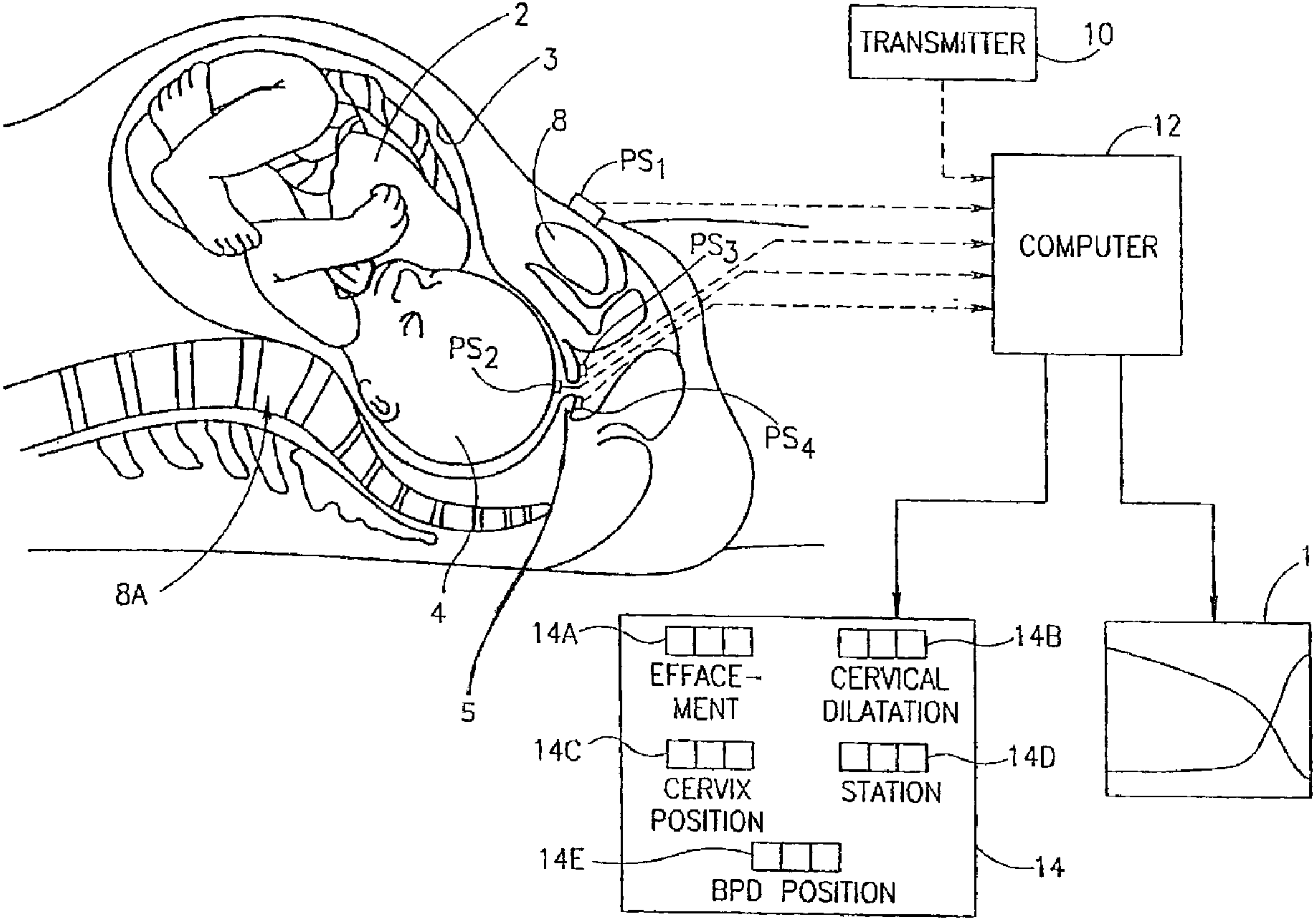

BASELINE FHR
BASELINE FHR
80
FHR
100
NO PERIODIC FHR CHANGE
NO PERIODIC FHR CHANGE
NO PERIODIC FHR CHANGE
4C

FIG.9


TRANSMITTER
10
2
3
8
PS_1
12
COMPUTER
PS_3
PS_2
PS_4
8A
4
5
16
14A
EFFACE-
MENT
14B
CERVICAL
DILATATION
14C
CERVIX
POSITION
14D
STATION
14E
BPD POSITION
14

(57) Abrégé(suite)/Abstract(continued):
monitoring the location of the fetal presenting part with respect to the predetermined point on the mother's pelvic bones. The location of the fetal presenting part may be indicated by a similar position sensor, or by imaging. Other conditions, such as effacement, cervical dilatation, and cervical position may also be monitored in a similar manner.