Oct. 24, 1967 D. P. GREGG 3,348,535

PARTURITIVE PHONE

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Fig. 1

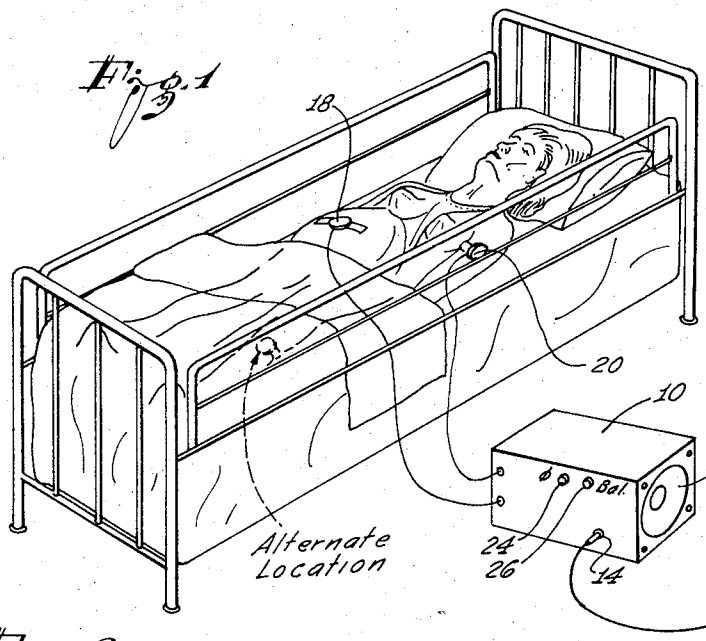


Fig. 6

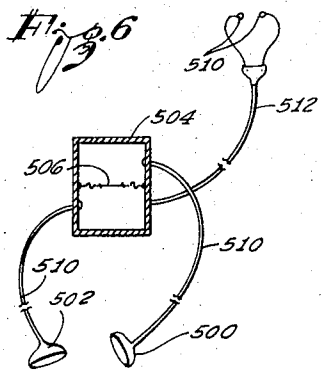


Fig. 2

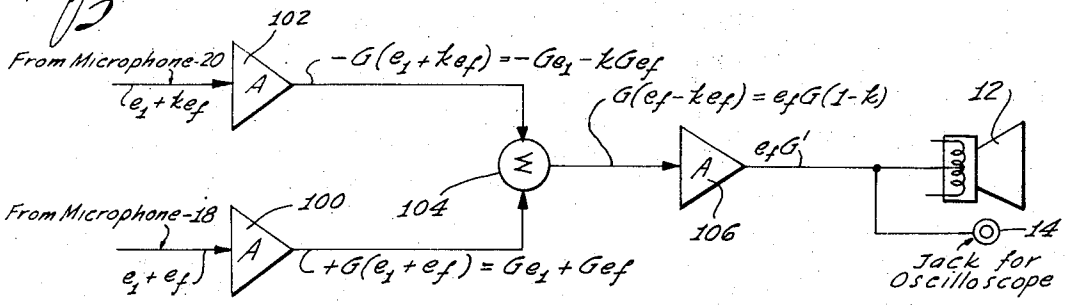
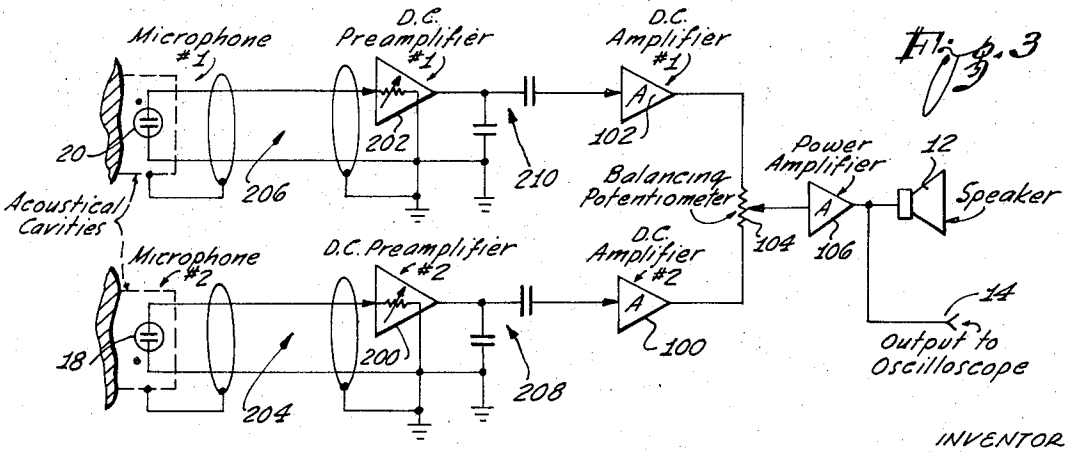


Fig. 3



INVENTOR
David Paul Gregg

By Keith D. Beecher
Attorney

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Fig. 4 (D.C. Preamplifier -200-)

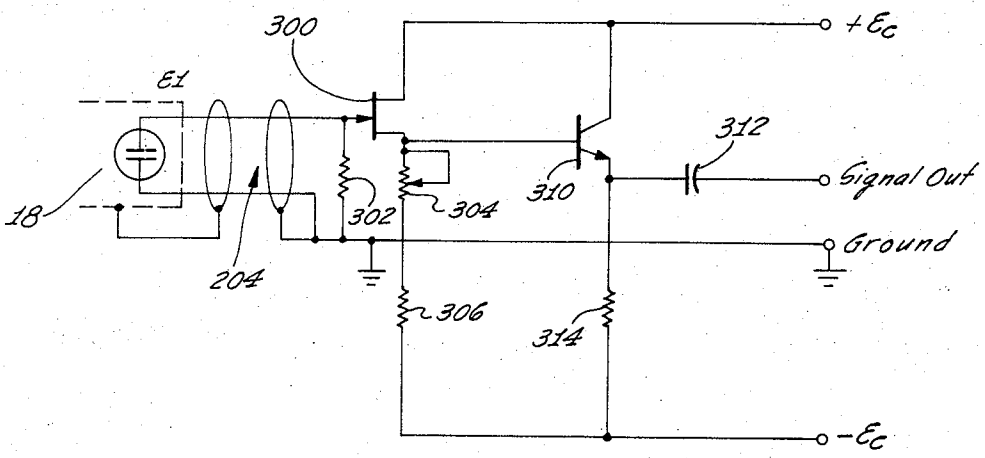
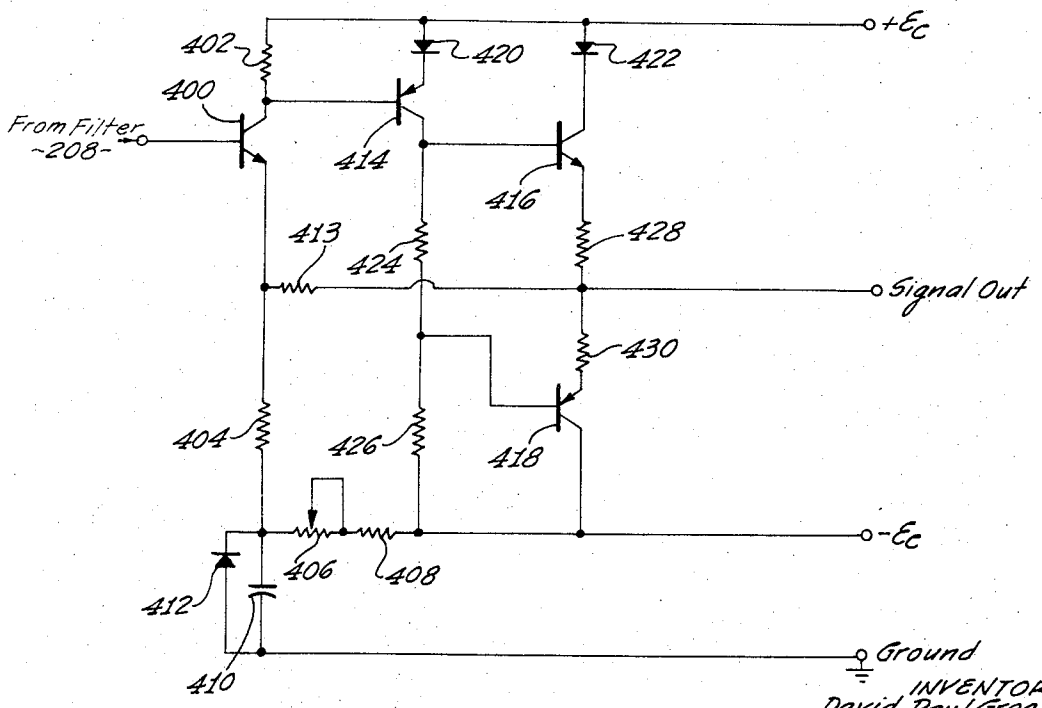


Fig. 5 (D.C. Amplifier -100-)



INVENTOR:
David Paul Gregg
By Keith D. Beecher
Attorney.

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PARTURITIVE PHONE

David Paul Gregg, 1936 Kelton Ave.,
Los Angeles, Calif. 90025

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The present invention relates to medical instruments and systems of the stethoscope type, and it relates more particularly to an instrument for monitoring the fetal heart beat during parturition.

It is well known that during the birth of a child there is a likelihood of strangulation by the umbilical cord. The resulting cessation of the fetal heart beat can be fatal within three minutes unless a Caersarean section, or other drastic means, are immediately put into effect.

It is important, therefore, that the fetal heart beat be monitored during parturition. It is usual practice for the obstetrician to have a stethoscope-type of hearing device mounted on his head, so that from time to time he can apply it to the mother's abdomen and determine whether the baby's heart is still beating. This, however, is an awkward procedure. Also, there is difficulty in separating the faint fetal heart beat from the dominant mother's heart beat when the usual stethoscopic type of instrument is used for this purpose.

An object of the present invention is to provide an improved medical instrument which serves to null out the mother's heart beat so that the infant's heart beat can be easily monitored during parturition.

Another object of the invention is to provide such an improved instrument which is predicated on electronic principles, and which is constructed so that the fetal heart beat can be continuously monitored and reproduced as an aural or visual signal.

In the embodiment to be described, two electro/acoustical transducers in the form of microphones, for example, are provided. A first of these microphones is positioned on the mother's abdomen in the vicinity of the fetus, and the other is positioned an appreciable distance from the mother's heart.

The first microphone picks up the weak fetal heart beat accompanied by the mother's stronger heart beat. The second microphone may be positioned, for example, on the mother's arm, or in some other location on the mother's anatomy where her heart beat may be received with essentially the same intensity as at the first location, but where the faint fetal heart beat is attenuated practically to zero.

The two microphones referred to in the preceding paragraph are connected to an electronic circuit which responds to the signals therefrom. The electronic circuit is constructed so that the signals representative of the mother's heart beat are essentially nulled out by a subtractive process, and the signal representative of the fetal heart beat is passed in amplified form. The latter signal may be converted into sound signals, for example, by means of a loud speaker. Moreover, the latter signal may be applied to an oscilloscope, or similar instrument, so as to provide a visual display.

Therefore, when the system of the invention is used during parturition, a positive and continuous monitoring of the fetal heart beat may be established. The fetal heart beat may be reproduced aurally on a loud speaker to be readily heard, and it may also be reproduced visually, so as to provide an instant alert to the obstetrician, or other attendants, should the heart beat fail.

The features of the invention which are believed to be new are set forth in the claims. The invention itself, however, together with other objects and advantages thereof, may best be understood by reference to the following description, when the description is taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is an illustrative example of the system and process of the invention, in actual practice;

FIGURE 2 is a block diagram representing schematically the function of the electric circuitry used in the embodiment to be described;

FIGURE 3 is a more detailed diagram of the electrical and electronic circuitry;

FIGURES 4 and 5 are circuit diagrams of various amplifier stages used in the circuit of FIGURE 3; and

FIGURE 6 is an acoustical embodiment of the invention.

As shown in FIGURE 1, the system and mechanism of the invention may be encased in a housing **10**. The housing **10** is equipped with a loud speaker **12**, and it also includes a jack **14**. An oscilloscope **16**, earphones, or other reproducing or display apparatus, may be plugged into the jack **14**, or other additional jacks may be provided.

In the practice of the invention, a first electro/acoustical transducer **18** is placed on the abdomen of the mother, for example, and it may be held in place by adhesive tape or other appropriate means. This first electro/acoustical transducer is connected to the electric circuit in the housing **10**. A second electro/acoustical transducer, in the form of a microphone **20** is similarly strapped, or otherwise affixed to a portion of the mother's anatomy displaced from the microphone **18**.

The microphone **20** may be positioned, for example, on the mother's arm, or on her leg (as shown as an alternate location in FIGURE 1), or on any other appropriate part of the mother's anatomy. The latter microphone **20** is also connected to the electronic circuit in the housing **10**. The circuit may be equipped with a phase adjustment **24**, and with a balancing adjustment **26**.

As mentioned above, the microphone **18** is placed on a location of the mother's anatomy such that it can detect not only the mother's heart beat, but also the relatively faint fetal heart beat. Both these heart beats are converted into respective electrical signals by the microphone, and the signals are applied to the circuit in the housing **10**.

The microphone **20**, on the other hand, is preferably positioned on the mother's anatomy at a location such that it may detect the mother's heart beat with essentially the same amplitude as detected by the microphone **18**, but where the fetal heart beat is attenuated essentially to zero. The microphone **20** converts the mother's heat beat at the latter location into an electrical signal and applies it to the circuit in the housing **10**.

As will be described, the aforesaid circuit in the housing **10** responds to the signals from the two microphones **18** and **20**, and it passes the signals from one of the microphones, for example, from the microphone **20** through an inverter amplifier, and passes the signals from the microphone **18**, for example, through a similar amplifier which does not invert the signals.

The resulting signals are summed algebraically, and it will be apparent that the signals representative of the mother's heart beat will be essentially nulled out. However, the signal representative of the fetal heart beat will be amplified and passed to the speaker **12** and to the oscilloscope **16**. Therefore, an aural and a visual representation of the fetal heart beat is provided continuously during parturition, and any cessation of the fetal heart beat is instantly detected.

As shown in FIGURE 2, it is assumed that the microphone **18** picks up the mother's heart beat and transforms it into a signal (e_1), and that it also picks up the fetal heart beat and transforms it into an electric signal (e_f). Both these signals are applied to a direct current amplifier

100 which has a gain G. Therefore, the output from the amplifier 100 may be expressed as:

$$+G(e_1+e_f)=Ge_1+Ge_f \quad (1)$$

The microphone 20, on the other hand, produces a signal corresponding to the mother's heart beat which will be assumed to have the same amplitude as the corresponding signal produced by the microphone 18, and will also be referred to as (e_1), and it also produces a signal corresponding to the fetal heart beat, the latter signal having essentially zero amplitude and will be expressed as (ke_f).

These latter signals are applied to a direct current amplifier 102 which, as mentioned, may perform a phase inversion on the signals. Of course, the microphone may be poled to provide opposite polarity signals, in which case the amplifier 102 need not perform a phase inversion. Therefore, in either case, the amplifier 102 produces an output which may be expressed as:

$$-G(e_1+ke_f)=-Ge_1-kGe_f \quad (2)$$

where: G is the gain of the amplifier 102 (assumed to be equal to the gain of the amplifier 100).

The signals from the amplifiers 100 and 102 are applied to a summing circuit 104 which may, for example, be in the form of a potentiometer or other resistance network. The network 104 algebraically sums the two outputs from the amplifiers 100 and 102, and it produces an output:

$$G(e_f-ke_f)=e_fG(1-k) \quad (3)$$

As mentioned, the signal ke_f corresponding to the fetal heart beat at the second location is essentially zero, so that to all intents and purposes k can be considered as zero.

The output from the summing network 104 is introduced to a power amplifier 106. The resulting output from the power amplifier represents a signal corresponding to the fetal heart beat, and this signal may be expressed (e_fG'). The latter amplified signal is applied to the speaker 12 and to the jack 14, so that it may be reproduced as a sound signal, and so that it may also be visually displayed by the oscilloscope 16.

As shown in the circuit of FIGURE 3, the signals from the microphones 18 and 20 may initially be passed through corresponding direct current pre-amplifiers 200 and 202. These pre-amplifiers may have adjustable gains, so that the signal amplitudes may be equalized. The microphones 18 and 20 are connected to the pre-amplifiers through usual shielded cables 204 and 206. The microphones 18 and 20 are shown as crystal microphones which include self-generating piezoelectric sensors. Appropriate acoustical cavities may be mounted on the microphones so as to provide optimum acoustical coupling between the microphones and the heart beat sources.

A high frequency filter 208 is interposed between the pre-amplifier 200 and the direct current amplifier 100. A similar high frequency filter 210 is interposed between the pre-amplifier 202 and the direct-current amplifier 102.

As shown in FIGURE 3, the balancing potentiometer controlled by the knob 26 in FIGURE 1 may serve as the summing network 104. An appropriate phase shift network (not shown) may be included in the circuit of either of the microphones, to be controlled by the knob 24, for example, so as to bring the appropriate signals into phase, so that optimum nulling may be achieved.

The pre-amplifiers 200 and 202 may, of course, be of any appropriate construction. A typical circuit for the pre-amplifier 200, for example, is shown in FIGURE 4. The direct-current pre-amplifier 202 may be similarly connected.

The cable 204 in the circuit of FIGURE 4 is connected to the gate electrode of a field effect transistor 300, and to a grounded resistor 302. This resistor, for example, may have a resistance of 300 megohms. The field effect transistor 300 is used, for example, because it exhibits the desired high impedance input characteristics. The input impedance of the circuit is limited to 300 megohms by the resistor 302.

The source electrode of the field effect transistor 300 is connected through a gain control potentiometer 304 and through a resistor 306 to the negative terminal of a 9-volt direct-current exciting source E_c. The potentiometer 304 may have a resistance of 100 kilo-ohms, and it provides for the desired gain adjustment. The resistor 306 may have a resistance of 40 kilo-ohms. The drain electrode of the field effect transistor is connected directly to the positive terminal of the source E_c.

The source electrode of the field effect transistor is also connected to the base of an NPN transistor 310. The NPN transistor is connected as an emitter follower, and its emitter is coupled through an appropriate coupling capacitor 312 to the output terminal. The capacitor 312 may have a capacitance of 150 microfarads. The collector of the transistor 310 is connected directly to the positive terminal of the aforesaid source, and the emitter is connected through a resistor 314 to the negative terminal. The resistor 314 may have a resistance of 10 kilo-ohms.

Likewise, the direct-current amplifiers 100 and 102 may have any suitable circuit configuration. An appropriate circuit for the direct-current amplifier 100 is shown in FIGURE 5. It is to be understood, of course, that the direct-current amplifier 102 may be similarly constructed.

The output from the filter 208 is applied to the base of an NPN transistor 400. This transistor is connected as a voltage amplifier, and its collector is connected through a resistor 402 to the positive terminal of the direct-current source, whereas its emitter is connected through a resistor 404, through a potentiometer 406, and through a resistor 408 to the negative terminal.

The junction of the resistors 404 and 406 is connected to a grounded capacitor 410, the capacitor being shunted by a diode 412. The emitter of the transistor 400 is also connected to a resistor 413. The resistor 402 may have a resistance of 10 kilo-ohms; the resistor 404 may have a resistance of 300 ohms; the potentiometer 406 may have a resistance of 50 kilo-ohms; the resistor 408 may have a resistance of 10 kilo-ohms; the capacitor 410 may have a capacity of 1000 microfarads; and the resistor 413 may have a resistance of 50 kilo-ohms.

The collector of the transistor 400 is also connected to the base of a transistor 414. The transistor 414 is connected to a complementary pair of emitter follower transistors 416 and 418. The transistor 414 and the transistor 418 are PNP transistors, whereas the transistor 416 is an NPN transistor.

The emitter of the transistor 414 is connected through a diode 420 to the positive terminal $+E_c$ of the direct-current source, whereas the collector of the transistor 416 is connected to that terminal through a diode 422. The output signal from the circuit is derived at the junction of a pair of resistors 428 and 430, which connect the emitters of the transistors 416 and 418; the junction also being connected to the resistor 413. A pair of resistors 424 and 426 connect the collector of the transistor 414 to the negative terminal ($-E_c$) of the direct-current source; and the junction of the resistors 426 and 428 is connected to the base of the transistor 418. The collector of the transistor 418 is directly connected to the negative terminal ($-E_c$) of the direct-current source.

The resistors 424 and 426 may each have a resistance of 390 ohms; and the resistors 428 and 430 may each have a resistance of 47 ohms.

The parturitive phone shown in FIGURE 6 shows the manner in which the objectives of the invention are obtained on a purely acoustical basis. The parturitive phone of FIGURE 6 includes a pair of stethoscope-like body contact pieces 500 and 502.

The assembly of FIGURE 6 also includes a differential diaphragm changer 504. A diaphragm 506 is mounted in the chamber 504. The body contact pieces 500

and **502** are coupled to the chamber **504** by tubes **508** and **510**, on opposite sides of the diaphragm.

The parturitive phone includes ear-pieces **510** which are coupled to the chamber **504** by way of a tube **512**.

In the latter embodiment, the body contact piece **500** may be placed on the mother in position to pick up both the mother's heart beat and the fetal heart beat; and the body contact piece **502** may be placed in position to pick up the mother's heat beat. Then the differential action of the diaphragm **506** in the chamber **504** causes only the fetal heart beat to be transmitted to the ear-piece **510**.

The invention provides, therefore, an improved parturitive phone which functions to separate the fetal heart beat from the dominant mother's heart beat, and to provide a continuous and positive indication of the fetal heart beat during the entire parturitive process.

While particular embodiments of the invention have been described, modifications may be made. It is intended to cover all such modifications in the appended claims.

What is claimed is:

1. Apparatus for detecting fetal heart beats during parturition, including: first electro-acoustical transducer means for sensing a mother's heart beat and the fetal heart beat and for producing respective first and second electrical signals in response thereto each with particular amplitude; second electro/acoustical transducer means for sensing the mother's heart beat to the substantial exclusion of the fetal heart beat and for producing a third signal in response to the mother's heart beat with a particular amplitude; circuit means coupled to said first and second transducer means and responsive to said electrical signals from said first and second transducer means for substantially nulling out said first and third electrical signals and for passing said second electrical signal; and reproducing means coupled to said circuit means for reproducing said second electrical signal.

2. Apparatus defined in claim **1** in which said circuit means includes a first amplifier for amplifying said first and second signals without phase inversion, and a second amplifier for amplifying said third and fourth signals with 180° phase inversion, and summing means coupled to said first and second amplifiers for algebraically adding said first signal to said third signal and said second signal to said fourth signal.

3. Apparatus for detecting fetal heart beats during parturition, including: first electro/acoustical transducer means adapted to be positioned on the mother in a location where the mother's heart beat and the fetal heart beat can be detected, each with a particular amplitude, said first transducer means developing a first electrical signal corresponding to the mother's heart beat and a second electrical signal corresponding to the fetal heart beat; second electro/acoustical transducer means adapted to be positioned on the mother in a location where the mother's heart beat can be detected with essentially the same amplitude as said particular amplitude and where the fetal heart beat is attenuated essentially to a zero amplitude, said second transducer means developing a third electrical signal corresponding to the mother's heart beat; circuit means coupled to said first and second transducer means and responsive to the signals from said first and second transducer means for nulling out said first and third signals and for amplifying said second signal; and reproducing means coupled to said circuit means for reproducing the second signal as amplified by said circuit means.

4. Apparatus for detecting fetal heart beats during parturition, including: first acoustical body-contact piece for detecting the mother's heart beat and the fetal heart beat at a particular location on the mother's anatomy; a second acoustical body-contact piece for detecting the mother's heart beat at a different location on the mother's anatomy; means coupled to said first and second body-contact pieces for nulling out the mother's heart beat as detected in the aforesaid two locations and for passing an acoustical signal representative of the fetal heart beat, said nulling means including a chamber and a diaphragm mounted in said chamber to respond differentially to acoustical signals derived from said first and second body-contact pieces; and further means coupled to said nulling means for reproducing said acoustical signal.

References Cited

UNITED STATES PATENTS

2,409,749	10/1946	Foulger et al.	128—2.06
2,658,505	11/1953	Sheer	128—2.05
2,669,986	2/1954	Crawley	128—2.1
2,827,040	3/1958	Gilford	128—2.05
3,052,756	9/1962	Seven et al.	179—1
3,171,892	3/1965	Pantle	179—1

OTHER REFERENCES

C. N. Smyth, "Foetal Phonocardiograph," pp. 1005–1009 of British Medical Journal for October 25, 1958.

RICHARD A. GAUDET, *Primary Examiner.*

SIMON BRODER, *Examiner.*