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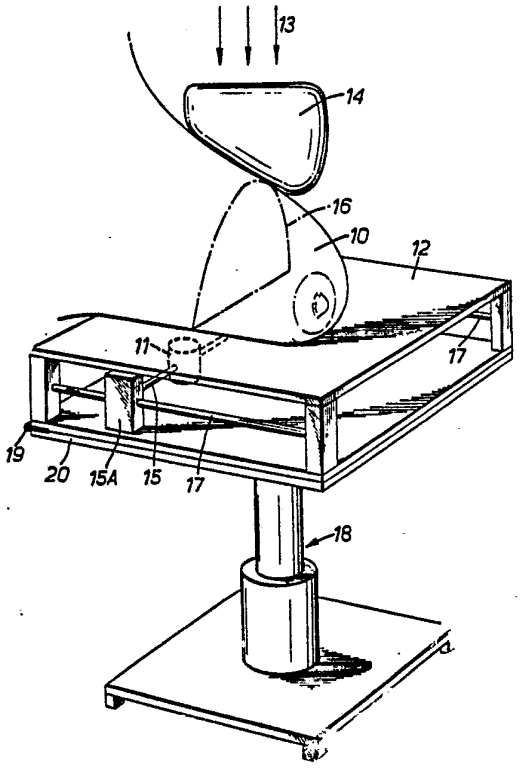
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(54) Title: APPARATUS FOR ULTRASONIC EXAMINATION OF DEFORMABLE OBJECTS

(57) Abstract

Apparatus to support a deformable object (10) for ultrasonic examination comprises an ultrasonically transparent plate (12) upon which the objet (10) can be supported, with an ultrasonic transducer (11) positioned below, but close to, the plate (12). The transducer (11) can be a single transducer, mounted to move parallel to the plate in substantially orthogonal directions, or it may be a linear array or a plurality of sector scanning transducers. Side plates (21), extending above the support plate (12), may be included to compress the object (10) laterally. One or each side plate (21) may be provided with a transducer (22) for lateral ultrasonic examination of the object (10). The support plate (12) may be shaped so that its surface is part of a cylindrical surface. A typical deformable object (10) is the female human breast. With the present invention, ultrasonic examination of the human breast can be made to directly complement its X-ray or xeromammographic image.



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TITLE: "APPARATUS FOR ULTRASONIC EXAMINATION OF DEFORMABLE OBJECTS"

TECHNICAL FIELD

This invention concerns ultrasonic examination of objects which, for any one of a variety of reasons, cannot conveniently be immersed in a water bath, or to which it is inconvenient to connect ultrasonic transducers through an ultrasonically transparent coupling plate. It is particularly applicable to the ultrasonic examination of a deformable object, one example of which is the female breast. Indeed, the present invention was conceived specifically to improve the value of echograms of the female breast, and for this reason the following description will concentrate on this application of the present invention, but it will be appreciated that the present invention is not limited to apparatus for use in the ultrasonic examination of the female breast.

BACKGROUND ART

Echograms are often used as diagnostic aids in medicine, and for this purpose they form but one tool of the diagnosing physician. Another tool of the physician is an X-ray film of the relevant part of the patient. Clearly, if both of these diagnostic tools are to be used, it is advantageous for the pictures presented by the echogram and the X-ray film to be complementary. Unfortunately, until now, this has not been possible when the part of the body that is under examination is the female breast, and the physician wishes to use an echogram in conjunction with an X-ray film of the breast, or with a xeromammographic image of the breast.

When a patient's breast is to be imaged by X-rays or xeromammography, the patient either sits down or lies on her side and the breast is positioned on an imaging surface, which is a photographic film in X-ray mammography, and a charged plate in xeromammography.

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Because the breast is a deformable organ, the patient is generally positioned to flatten the breast against the imaging surface and anteroposterior, lateral and inclined projection views are usually taken. In some instances, additional pressure from above the breast may be employed, to position more of the tissues on the imaging surface and to attain an even thickness distribution of the tissues on the imaging surface, giving a more balanced image exposure. The combination of the support from below by the imaging surface and the compression from above distorts the breast in a manner specific to the X-ray imaging method.

Ultrasound has been used for a number of years as a breast imaging technique. It is used in one of several ways. In the contact examination, the patient is generally examined in the prone position in which, due to gravity, the breast assumes a shape different from the compressed shape encountered in the X-ray imaging technique. Similarly, when contact examinations are performed with the patient sitting, no supporting fixture is employed and the breast assumes a different shape. Water path examinations are also commonly employed. In such examinations, the patient is examined either in the prone position with a water bag lowered on to the breast or in the supine position with the breast immersed either free or partially compressed by a membrane. Again, the breast assumes a shape different from that encountered in an X-ray examination.

It will thus be seen, as physicians have noted, that due to the different shape of the breast in each form of imaging, it is difficult to accurately correlate the detail obtained by the X-ray (or xeromammographic) methods and the ultrasound techniques, for not only do the breast tissues occupy different spatial positions relative to the patient's fixed anatomical land marks such as ribs and the nipple, but also compression of the breast can redistribute the composition of the

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constituent tissues and this further complicates the correlation as different compressions are used in the two techniques.

DISCLOSURE OF THE PRESENT INVENTION

It is an objective of this invention to provide apparatus with which ultrasonic examination of the breast may be performed to provide an ultrasonic image which can be readily correlated with an X-ray image of the breast.

To achieve this objective, an ultrasonically transparent plate is provided to support the breast, and optionally permit a required compression or manipulation of the breast tissues, and a transducer arrangement is mounted adjacent to the underside of the plate. With this apparatus, it is possible to arrange for the breast to have the same shape as it has adopted for a prior X-ray examination, and consequently it is possible for a diagnostician to visually correlate the images provided by the two imaging methods.

Accordingly, the present invention, in its broadest form, provides apparent for ultrasonic examination of a deformable object comprising

a) an ultrasonically transparent plate, adapted to be positioned in contact with the object; and

b) at least one transducer mounted in close proximity to the plate and adapted to transmit a beam of ultrasonic energy through the plate and into the object, and to receive reflections of the ultrasonic energy from acoustic discontinuities within the object.

The at least one transducer may be a single transducer mounted for independent movement in two directions parallel to the plate. Alternatively, it may be an array of transducers, adapted to be electronically switched to produce beams of ultrasonic energy at different locations over the plate. Yet again, the at least one transducer may be a plurality of sector

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scanning transducers, a curved array of transducers, or any suitable transducer arrangement known to persons skilled in this art.

The plate may be a flat plate, or it may be curved to have a surface which is part of the surface of a cylinder. If it is a flat plate, a pair of side plates (one or both of which are optionally fitted with a further transducer means) may be mounted immediately above the flat plate. The plate may be rotatable and/or tiltable.

In a particular application of the present invention (as will be evident from the above text), the object to be examined is a female breast.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective sketch which illustrates the use of one form of apparatus used for the ultrasonic examination of the female breast.

Figure 2 is an end-on view of a modified form of the apparatus of Figure 1, in use.

Figure 3 is an end-on view of another embodiment of the apparatus of the present invention, employing a curved coupling plate and multiple sector scanning transducers, showing how this embodiment is used.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

In the embodiment of the invention illustrated in Figure 1, the breast 10 is positioned on a stationary, generally horizontal, flat, ultrasonically transparent, rigid plate 12. The plate 12 is positioned relative to the patient so that it compresses the breast 10 from underneath, thus making the breast 10 conform to the shape it would adopt in an X-ray examination.

The plate 12 may be of any suitable ultrasonically transparent material, including metal and dense plastics material. Foamed plastics materials and fibrous

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materials are not ultrasonically transparent and thus cannot be used for plate 12. A particularly suitable material is a rigid polycarbonate plastic, which is both strong and ultrasonically transparent.

An ultrasonic transducer 11 (shown partly in dashed outline) is mounted for linear movement along rail 15 beneath the plate 12. The rail 15 is itself supported by a pair of blocks 15A which are adapted to be moved on rails 17. The mechanism for moving the transducer 11 on the rail 15 and for moving blocks 15A on rails 17 is not shown, but various forms of such mechanism are already available for this purpose and any suitable one of those known mechanisms may be used. If an electrical drive is used for this purpose, a foot control may conveniently be used, so that the transducer is driven back and forth at a variable speed which is determined by the examiner, who notes the varying appearance of tissues in response to compressions. Stopping the movement of the transducer then permits detailed examination of tissues of special interest, which can be brought in and out of the viewing plane by manipulating the compression applied to the breast.

The arrangement illustrated in Figure 1 also allows real time ultrasonic viewing of the tissues of the breast in any required coronal plane 16 to be obtained. In addition, the transducer may be set to any X-Y coordinates on the plate for ultrasonic examination of specific tissues, such as those noted on an X-ray film. Such an ultrasonic examination may be required to determine the Z coordinate of tissue of interest. The apparatus may also be used to effect a X-Y raster scan of the whole breast.

Those skilled in ultrasonic examination will appreciate that ultrasonic scanning in a single plane may also be achieved by using a linear array transducer, and that a linear array transducer may be moved in a direction perpendicular to the linear array to effect a

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volume scan of an object. Furthermore, manual scanning of a single or multiple transducer, or using one or several mechanically oscillated or rotated transducers, or phased array electronic scanners, or the use of two dimensional arrays, may also be used to obtain required ultrasonic images of an object. All such known arrangements may be used with the present invention.

The coupling of ultrasonic energy between transducer 11, the plate 12 and the breast 10 is normally effected by a layer of coupling gel or oil, the coupling layer being placed on the breast, the plate and the transducer prior to use of the apparatus. Alternatively, the plate 12 may contain appropriate means (such as small grooves) to enable a continuous feeding of coupling material to the appropriate surfaces during the ultrasonic examination.

In the embodiment illustrated in Figure 1, the apparatus is used to obtain an ultrasonic image of the breast 10 which is comparable to the supero-inferior X-ray image. The direction 13 of the X-rays that would be used to obtain that image is indicated in the Figure. When an X-ray image is being obtained, a film on a suitable support replaces the ultrasonically transparent plate 12.

In X-ray examination, external compression of the breast is often used. Similar compression to that used in X-ray examination may be achieved in use of the present invention with an air or water filled balloon 14. Alternative methods of compression include the use of sand bags or vacuum devices. However, compression of the breast is not essential. Indeed, it is often preferable for the top surface of the breast to be left free to be formed into any desired shape by the hand of the examiner, who may manipulate the breast to optimise the visualisation of detail of interest. Manual manipulation may be preferably employed in biopsy studies where, once the plane of interest has been

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selected, the position of the biopsy device relative to the internal tissue may be ascertained by noting the distortion of the skin by the pressure of the biopsy device. The present invention may be used with advantage in this situation, with the ultrasonic viewing employed to guide the biopsy device and ensure that the tissues of interest are selected for biopsy.

It will also be clear that forming the breast to the shape used for X-ray examination enables ready correlation of information obtained by X-ray examination and ultrasonic imaging.

Several optional features have been included in the embodiment illustrated in Figure 1. These optional features include -

a) telescopic height adjustment means 18 for altering the Z coordinate of the plate 12 (this feature may be used to accommodate the plate for the different heights of patients and to provide varying degrees of compression of the breast from below);

b) a hinge 19, connecting the assembly containing plate 12 and transducer 11 to a lower support plate 20, to enable the assembly to be tilted to allow better visualisation of detail close to the chest wall; and

c) a rotating ball arrangement (obscured) at the junction of the telescopic arrangement 18 and support plate 20 to allow the assembly containing plate 12 and transducer 11 to be positioned for acquisition of images corresponding to lateral and obliquely inclined X-ray views, by altering the position of the ultrasonically transparent coupling plate 12 relative to the breast.

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In the alternative form of the apparatus, shown in Figure 2, the ultrasonic coupling plate 12 and the underneath transducer 11 are complemented by the use of side plates 21. These side plates 21 are used to compress the lateral edges of the breast 10, thus allowing better ultrasonic visualisation of detail located near those areas. This form of the apparatus also includes the optional complementary side transducers 22, which are used to effect lateral ultrasonic examinations of the breast. Together with the underneath transducer 11, these side transducers allow the acquisition of compound scan images of the breast. Alternatively the side transducers 22 may be used individually and separately from the transducer 11. When the side transducers 22 are mounted on each plate 21, the transducers 22 are actuated alternately, to avoid the possibility of pulses from one side transducer interfering with the echoes received by the other side transducer.

The further form of the apparatus illustrated in Figure 3 uses a curved plate 32 to facilitate coupling to the lateral edges of the breast. Multiple sector scanning transducers 34 are used for the ultrasonic examination. Alternatively, a curved array transducer may be coupled to the plate 32 and used for the ultrasonic examination of the breast.

Although the invention has been described with reference to particular embodiments, it is to be understood that these embodiments are illustrative of the application of the invention, and that various modifications may be made to the embodiments, and other arrangements may be included, without departing from the spirit and scope of the invention. For example it is possible to combine the use of this apparatus with X-ray equipment, so that the two examinations may be performed on the one instrument.

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INDUSTRIAL APPLICABILITY

The apparatus of the present invention is of particular value in hospitals, clinics, doctors' surgeries and the like, where diagnostic clinical examinations of deformable objects - such as the female breast - are carried out. However, the invention is not limited to such applications, but may be used in the ultrasonic examination of any deformable object.

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CLAIMS

1. Apparatus for ultrasonic examination of a deformable object (10) comprising:
   a) an ultrasonically transparent plate (12), adapted to be positioned in contact with the object (10); and
   b) at least one transducer (11) mounted in close proximity to the plate (12) and adapted to transmit a beam of ultrasonic energy through the plate (12) and into the object (10), and to receive reflections of the ultrasonic energy from acoustic discontinuities within the object (10).

2. Apparatus as defined in claim 1, in which the at least one transducer (11) is a single transducer adapted to be moved in two orthogonal directions, but parallel to the surface of the plate (12).

3. Apparatus as defined in claim 1, in which the at least one transducer is an electronically switched, linear array transducer extending across at least part of the underside of the plate (12), the linear array transducer being mounted for movement parallel to the surface of the plate (12), in a direction which is perpendicular to the elongate direction of the linear array.

4. Apparatus as defined in claim 1, in which the at least one transducer is a plurality of sector scanning transducers.

5. Apparatus as defined in claim 2, claim 3 or claim 4, in which the surface of the plate (12) has a shape which is part of the surface of a cylinder.

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6. Apparatus as defined in claim 1, in which the surface of the plate (12) is flat and the plate (12) is provided with a pair of side plates (21) extending upwardly therefrom.

7. Apparatus as defined in claim 6, in which at least one of the side plates (21) is provided with an ultrasonic transducer (22) adapted to effect lateral ultrasonic examination of the object.

8. Apparatus as defined in any preceding claim, including means to support the plate (12), said support means having height adjustment means (18) to enable the height of the plate to be varied.

9. Apparatus as defined in claim 8, including means to enable the plate (12) to be tilted relative to said support means.

10. Apparatus as defined in any preceding claim, including means (14) to apply pressure to the object (10) when supported on the plate (12).

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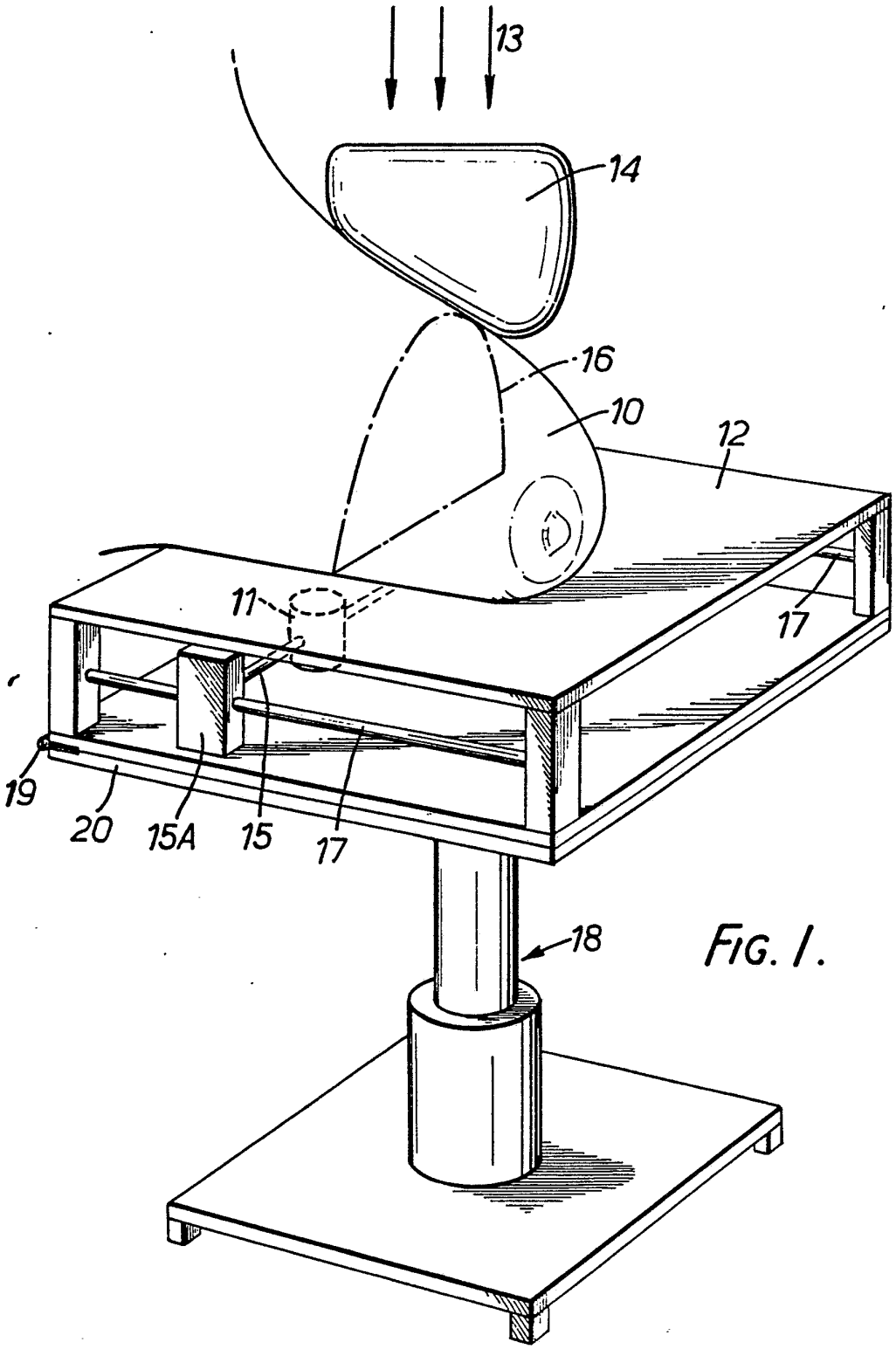


FIG. 1.

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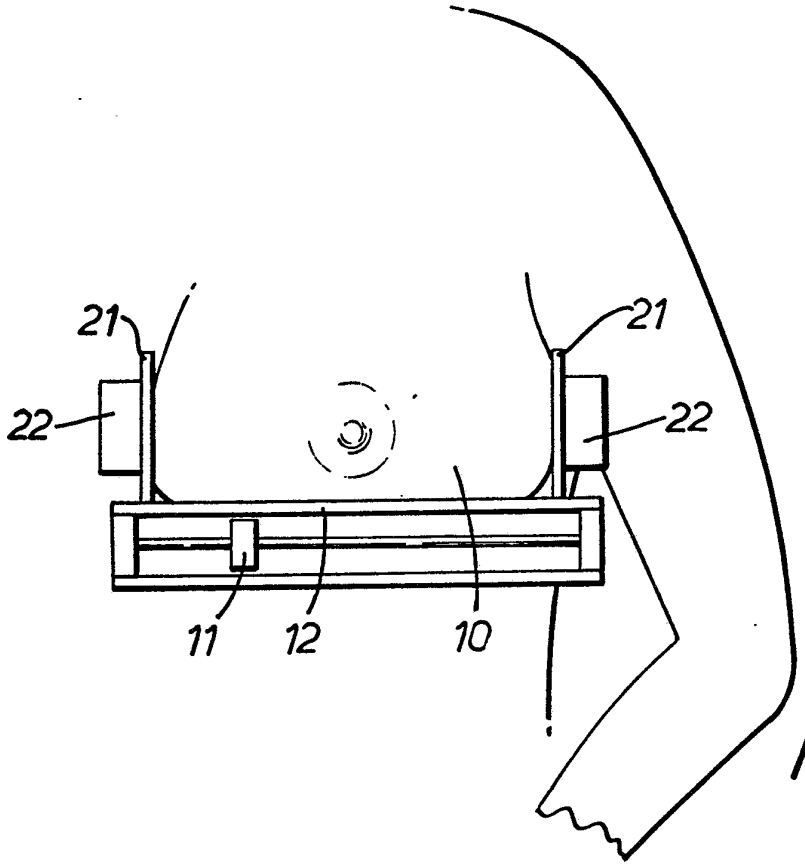


FIG.2.

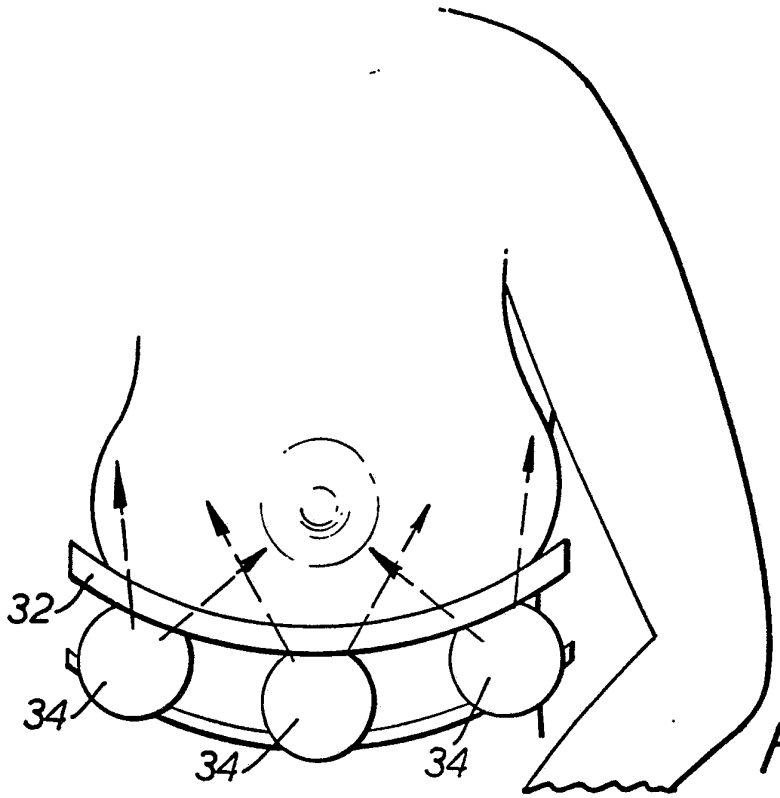


FIG.3.

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INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 82/00187

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[3] A61B 10/00; G01N 29/04

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	A61B 10/00; G01N 23/00 to 23/24; G01N 29/00 to 29/04.
US Cl.	128-2V, 73-601, 73-644

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

AU : IPC, A61B 10/00; G01N 29/00, 29/04;
Australian Classification: 87.4

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US,A, 4274421 (DORY) 23 June 1981 (23.06.81) See fig. 1 and col. 2 lines 28-32.	1
X	US,A, 4248090 (GLENN) 3 February 1981 (03.02.81) See fig. 3 and col. 5 lines 8-14.	1
X	US,A, 4211949 (BRISKEN) 8 July 1980 (08.07.80) See col. 2 lines 34-56	1,4
X,Y	US,A, 3908446 (MRUK) 30 September 1975 (30.09.75) See Fig 1.	1,5
X	US,A, 3585847 (BRENDEN) 22 June 1971 (22.06.72) See fig 19, col 14 lines 25-53	1,10
X	US,A, 3556081 (JONES) 19 January 1971 (19.01.71) See col. 3 lines 31-39 and fig. 1.	1,10
X	US,A, 3448606 (FLAHERTY) 10 June 1969 (10.06.69) See col 5 lines 35-38 and col 6 lines 5-28	1,2
X	GB,A, 1540673 (SRI INTERNATIONAL) 14 February 1979 (14.02.79) See Fig. 2 and Pg 2 lines 54-58.	1

* Special categories of cited documents: [15]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
25 January 1983 (25.01.83)	28 JANUARY 1983 (28-01-1983)
International Searching Authority [1]	**Signature of Authorized Officer [20]**
AUSTRALIAN PATENT OFFICE	P.F. GOTHAM

III DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, 16 with indication, where appropriate, of the relevant passages 17	Relevant to Claim No 18
Y	AU,A, 44653/79 (COMMONWEALTH OF AUSTRALIA) 6 September 1979 (06.09.79) See Fig 1	2
Y	AU,B, 39128/78 (514529)(COMMONWEALTH OF AUSTRALIA 21 December 1978 (21.12.78) See page 18 lines 18-24 and page 22 lines 3-9	2
Y	AU,B, 30401/77 (495970)(SMITH KLINE INSTRUMENTS INCORPORATED) 21 September 1978 (21.09.78) See page 3	4
X	AU,B, 22682/77 (506976)(RCA CORPORATION) 31 August 1978 (31.08.78) See fig. 2.	1
X	DE,A, 1773514 (SIEMENS AG) 25 November 1971 25.11.71) See fig. 2.	1
A	US,A, 4130112 (FRAZER) 19 December 1978 (19.12.78) See fig 1.	1
A	DE,A, 2314328 (SIEMENS AG.) 26 September 1974 (26.09.74) See fig. 1.	1