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(71) Applicant: **TECHNICARE CORPORATION**
29100 Aurora Road
Solon, Ohio 44139(US)

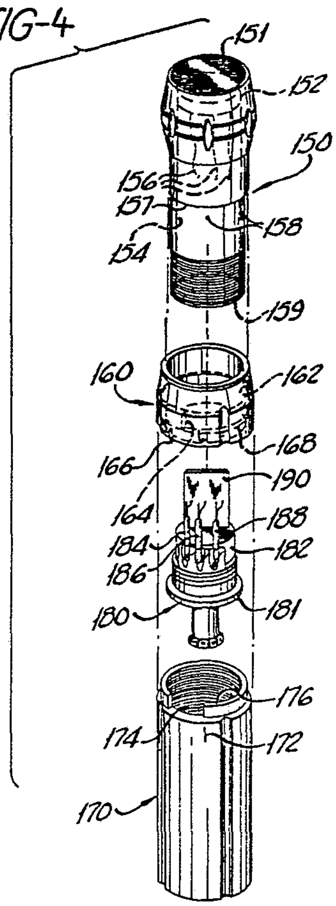
(72) Inventor: **Kaminski, Perry**
Parkway Court South Hills
Lewistown Pennsylvania(US)
Inventor: **Larson, Eugene A.**
R.D. No. 4, Box 76
Lewistown Pennsylvania(US)

(74) Representative: **Colgan, Stephen James et al**
CARPMAELS & RANSFORD 43 Bloomsbury Square
London WC1A 2RA.(GB)

(54) Dual aperture ultrasonic transducer probe assembly.

(57) The present invention provides a dual aperture ultrasonic transducer probe assembly for diagnostic imaging which uses a reed switch (184), located in an electrically shielded interior space in the probe housing and operated by a magnet (164) located external to said shielded interior region, to change the focal range of the transducer (152) without physically interrupting the shielding.

FIG-4



EP 0 196 139 A2

DUAL APERTURE ULTRASONIC TRANSDUCER PROBE ASSEMBLY

This application is a divisional application derived from our co-pending European Application No. 83304222.9 - (publication No. 0 102 179) filed on 6th July, 1983.

This invention which is the subject of the above application relates to ultrasonic transducers for diagnostic imaging of a novel geometric design with reduced sidelobe patterns, and provides an ultrasonic transducer assembly including a piezoelectric material, the transducer exhibiting an effective radiating surface having a center point characterised in that said effective radiating surface has an aspheric, semi-conical configuration resembling a concave spherical surface with opposite sides relative to the center of the surface canted toward each other.

The present invention relates to a dual aperture ultrasonic transducer probe assembly for diagnostic imaging.

Ultrasonic transducers are used in ultrasonic diagnostic systems to transmit waves of ultrasonic energy into a patient's body. Tissue interfaces in the body reflect some of this energy back toward the transducer in the form of echoes. The echoes are received by the transducer and converted into electrical signals. The signals may be processed by associating them with their times of arrival to reconstruct an image of the tissue or make fluid flow measurements.

In many applications of ultrasound it is desirable to be able to focus the waves or beams of ultrasonic energy at a particular tissue depth. Such focusing permits the reconstruction of images of good lateral resolution at a particular tissue depth of interest, for instance. Focusing may be done in the signal processing, as in the case of phased arrays, or may be provided by the geometric shape of the transducer. Geometric focusing advantageously eliminates much electrical complexity usually required to achieve the same result in the signal processing section of the system. However, geometric focal characteristics are idealized normally for only a single focal point or line of focal points, which restricts the range of good image resolution.

This restriction has been overcome by transducers having selectable geometric focal characteristics. A selectable focus transducer is shown in U.S. Patent 4,138 895. The transducer there shown comprises a disc divided into a center electroded region and an annular electroded region. A user can select just the center electrode for a large depth of focus or the central and annular regions together for a smaller depth of focus. An acoustic lens provides the transducer arrangement with the desired aperture with point focal characteristics.

Another important characteristic of transducers are sidelobe patterns. Transducers, like antennas, have transmissive characteristics than can be analyzed in terms of main and sidelobes. It is desirable in general to have small sidelobes for an ultrasonic transducer, since large sidelobes can result in the reception and introduction of noise in a reproduced ultrasound image

It is desirable, then, for an ultrasonic transducer to have good geometric focal characteristics which are adjustable so as to provide good resolution over a range of tissue depths. It is further desirable to reduce the transducer sidelobe patterns so as to minimize noise in the reproduced image.

The present invention provides a dual aperture ultrasonic probe assembly for an ultrasonic diagnostic system comprising:

a housing having an electrically shielded interior space;

a dual aperture transducer having first and second electrically separate regions, said transducer being located at one end of said housing and not exhibiting an aspheric, semiconical effective radiating surface;

means located in a wall of said housing, for making an electrical connection between said interior space and the exterior of said housing;

a reed switch, located in said shielded interior space and connected to said first and second transducer regions and said electrical connection means for selectively coupling said regions to said connection means; and

a magnet located external to said shielded interior space and movably mounted so as to selectively open and close said reed switch for varying the coupling of said transducer regions to said electrical connection means.

A probe assembly of this type, but used in connection with a transducer exhibiting an aspheric, semiconical effective radiating surface, is claimed in parent application No. 83304222.9.

Preferably, the reed switch has a first terminal coupled to said first transducer region and a second terminal coupled to said second transducer region and said electrical connection means comprises an r.f. connector having a conductor connected to said first reed switch terminal.

The assembly preferably further comprises a tuned circuit located in said shielded interior space and a second reed switch located in said shielded interior space in close proximity to said external magnet and connected to said transducer and said tuned circuit for selectively coupling said tuned circuit to said transducer.

The assembly may include an annulus of backing material affixed to the back of the transducer around the perimeter thereof, whereby sidelobes of the transducer are reduced by apodisation.

Preferably, the transducer material is divided into a center disc and an annular ring. When the center disc is activated, the range of optimal focus is located a relatively short distance from the transducer. When both the center disc and annular ring are activated, the range of optimal focus is located at a relatively greater distance from the transducer.

In the probe assembly of the present invention, the transducer electronics including the switch contacts are surrounded by a continuous shield in order to prevent the introduction of noise into the received echo signals. The use of a reed switch thus permits the focal ranges to be switched without physically interrupting the shield and hence impairing the noise characteristic of the transducer assembly

In the drawings:

FIGURES 1a and 1b illustrate idealized aperture and lobe patterns for a conical surface transducer;

FIGURES 2a and 2b illustrate idealized aperture and lobe patterns for a spherical surface transducer;

FIGURES 3a and 3b illustrate idealized dual aperture spherical and conical transducers; and

FIGURE 4 is an assembly drawing of a transducer probe constructed in accordance with the present invention.

Referring first to FIGURE 1a, a conical transducer is shown in cross-section. The transducer includes a conical surface 12 of piezoelectric ceramic material on a backer 10. The conical transducer exhibits an idealized aperture outlined at 16, which comprises a line of geometric focal points 14 emanating from the center of the transducer. Conical transducers are advantageous in that they exhibit a narrow region of sharply defined focal points. Their disadvantage is that the energy emitted by the conical surface is relatively evenly distributed over the line of focal poionts. It would be desirable to be able to concentrate the emitted energy in a particular region of the aperture, so as to improve the sensitivity of the transducer at a particular tissue depth of interest.

FIGURE 2a illustrates a spherical transducer in cross-section. This transducer includes a spherical surface 22 of piezoelectric material mounted on a backer 20. The spherical transducer exhibits an idealized aperture outlined at 26, which contains a single geometric focal point 24. The ultrasonic energy emitted from the spherical surface of the transducer 22 converges at this point, and diverges beyond it. The spherical transducer is capable of producing sharply focussed images of tissue in the vicinity of the geometric focal point 24 by reason of the concentrated ultrasonic energy at the point. However, the aperture is only sharply focused at one point, the resolution degrading at regions removed from this point.

It is desirable for a transducer to exhibit a radiation/reception pattern with reduced sidelobes, since signals received from the sidelobe regions can introduce noise which will degrade image quality. A conical transducer such as that shown in FIGURE 1a will exhibit a lobe pattern as shown in FIGURE 1b, with a large main lobe 40 and sizeable sidelobes 42, 42'. The large sidelobes 42 and 42' are undesirable in an ultrasonic diagnostic system.

The spherial transducer of FIGURE 2a will exhibit a more acceptable lobe pattern as shown in FIGURE 2b. The pattern there shown includes a large main lobe 50 and small sidelobes 52, 52'.

The lobe pattern of a transducer can be improved by providing backing material around the outer perimeter of the transducer. This ring of backing material damps vibrations at the outer perimeter of the piezoelectric material thereby reducing the energy radiated from the perimeter of the piezoelectric material. For dual focus, two area transducers, the ring of backing material may be extended to back the central region to damp vibrations at the perimeter of the central region when it is operated alone. This damping technique, generally referred to as apodizing, causes the transducer to be a non-uniform radiator, which "smears" the small side lobes of the transducer.

A comparison of idealized apertures of different dual focus transducers is shown in FIGURES 3a and 3b. FIGURE 3a illustrates the focal pattern of a simple dual aperture spherical transducer, including a central spherical region 120 and an outer annular region 122. When both regions 120 and 122 of the transducer are activated simultaneously the transducer exhibits an aperture outlined at 124, which narrows sharply at a focal region 125. Focusing is ineffective beyond the near field limit 129 of the transducer, which is approximately equal to the radius of the transducer squared, divided by the wavelength of operation. The near field limit 129 is thus a linear function of the area of the transducer, which in this case is the total of both regions 120 and 122.

When the spherical transducer is switched to operate in the near field using only the center region 120, the aperture is as outlined by dotted lines 126. This aperture produces a focal region 127 closer to the transducer, with a near field limit at 128 by reason of the reduced area of the transducer. The aperture outlined at 126 does not narrow as sharply as the aperture outlined at 124, however, and the focal region 127 has a greater lateral dimension 1 than focal region 125. This is because the focus is changed by changing the near field limit from 129 to 128; the geometric focus remains the same, generally located slightly beyond the far focal region 125.

FIGURE 3b illustrates the focal pattern of a simple dual aperture conical transducer having an inner conical surface 130 and an outer annular surface 132. When the inner conical surface 130 is activated alone, the energy from surface 130 focuses along the broken line shown at 137 and bounded by dotted lines 136. When both regions 130 and 132 are activated, the line of focal points is extended to include the points indicated at 135 as well as those at 137, bounded by dashed lines 134. Switching from operation using both regions to operation using only the center region 130 reduces the near field limit, since the transducer area changes, and also reduces the geometric focal length to only the focal points included in aperture outline 136. A line of distributed energy points is produced in both cases.

A dual aperture ultrasonic transducer is conveniently mounted in a probe assembly according to the present invention such as that shown in FIGURE 4. The probe assembly there shown advantageously provides an electrically shielded environment which reduces the tendency to pick up stray electronic interference. The probe assembly also provides a means for switching the focus of the transducer in a manner which does not interrupt the shielded environment. As the focus of the transducer is switched, the tuning of the transducer is also changed and a signal is provided which indicates the selected focal characteristics.

The probe assembly of FIGURE 4 includes a forward plastic cylindrical section 150 with a closed acoustic window face 151. The transducer 152 is located behind the window 151. Leads 156 extend from the separate regions of the transducer. The interior of the cylindrical section 150 is lined with a nonmagnetic shield 154 such as copper. The rear portion of the cylindrical section 150 narrows to a smaller diameter as indicated by dividing ridge 157. Two dimples shown at 158 are provided on the outside of the narrow portion which form a portion of the detent mechanism of the switch. The end 159 of the cylindrical section 150 is open.

A plastic ring 160 slides over the narrow portion of the cylindrical section 150 up to the ridge 157. On the inner surface of the ring 160 is a small ball 162 which rides between the dimples 158 and snaps into them to provide a detent mechanism for the ring. A groove 168 is formed around the inner surface of the ring to hold a magnet 164 in a predetermined position relative to the ball bearing 162. A small pin 166 extends from the inner surface of the ring at the bottom of the ring.

With the ring 160 in place on the forward cylindrical section 150, a rear cylindrical section 170 slides over the remainder of the narrow portion of section 150. A recessed collar 176 is then located under the ring 160. The collar

176 has a slot 174 in it so that pin 166 can move from one end of the slot to the other as the ring 160 is turned. The pin and slot thereby provide a stop for the ring to permit the ring to be turned only through the arc of the slot.

Finally, the wires 156 from the transducer are soldered to a small printed circuit board 190, mounted on an r.f. connector 180. The r.f. connector 180 is inserted into the open end 159 of the section 150 up to the lip 181 of the connector. Mounted on the connector at a plastic ring 182 are three reed switches 184, 186 and 188. The reed switches are wired to the printed circuit board 190. When the connector is inserted in the section 150 in the proper position, the reed switches are located under either side of the arc transversed by the magnet 164 as the ring 160 is turned. When the ring is turned to one detent position the magnet 164 is located over reed switches 184 and 186 to close them. And when the ring is in its other detent position the magnet is located over reed switch 188 to close it. The r.f. connector 180 and copper shield 154 provide a completely shielded cavity for the wiring, printed circuit board, switches, and board components in the inside of the section 150.

Turning the ring performs three switching functions in the probe assembly. First, the focal characteristics of the transducer are switched between short focus using only the central disc of the transducer, and long focus by connecting the central disc and annular ring of the transducer together to be activated simultaneously. Second, the tuning of the circuitry on circuit board 190 is switched to match the respective electrical characteristics of the transducer in the two operating modes. Third, a resistance value on the circuit board is changed to produce a signal indicative of the operating mode, which signal is coupled out through the connector along with signals to and from the transducer.

Claims

1. A dual aperture ultrasonic transducer probe assembly for an ultrasonic diagnostic system comprising:

a housing (150, 160, 170) having an electrically shielded interior space;

a dual aperture transducer (152) having first and second electrically separate regions, said transducer (152) being located at one end of said housing (150) and not exhibiting an aspheric, semiconical effective radiating surface;

means (180), located in a wall of said housing, for making an electrical connection between said interior space and the exterior of said housing;

a reed switch (184), located in said shielded interior space and connected to said first and second transducer regions and said electrical connection means (180) for selectively coupling said regions to said connection means (180); and

a magnet (164) located external to said shielded interior space and movably mounted so as to selectively open and close said reed switch (184) for varying the coupling of said transducer regions to said electrical connection means - (180).

2. The assembly of claim 1, wherein said reed switch (184) has a first terminal coupled to said first transducer region and a second terminal coupled to said second transducer region, and

wherein said electrical connection means comprises an r.f. connector (180) having a conductor connected to said first reed switch terminal.

3. The assembly of claim 2, further comprising:

a tuned circuit (190) located in said shielded interior space; and

a second reed switch (186) located in said shielded interior space in close proximity to said external magnet (164) and connected to said transducer and said tuned circuit (190) for selectively coupling said tuned circuit (190) to said transducer.

4. The assembly of any one of claims 1 to 3, further comprising an annulus of backing material affixed to the back of the transducer (152) around the perimeter thereof.

FIG-1a

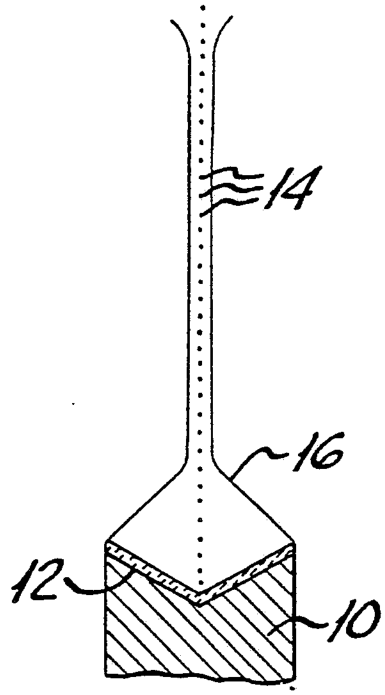


FIG-1b

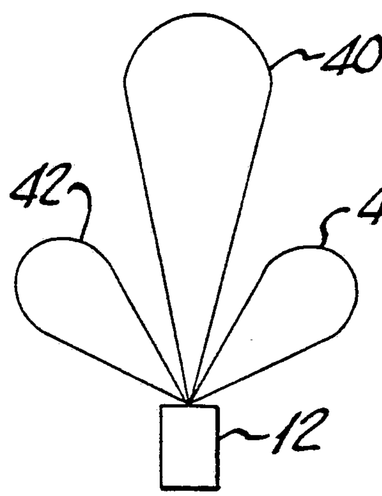


FIG-2a

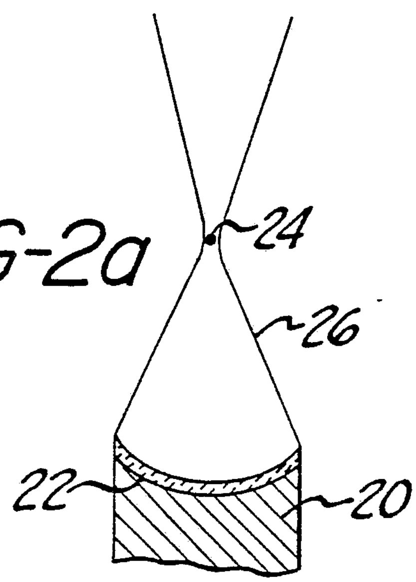


FIG-2b

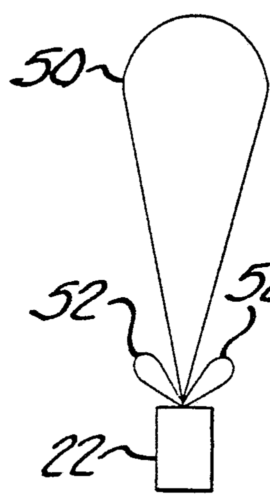


FIG-3a

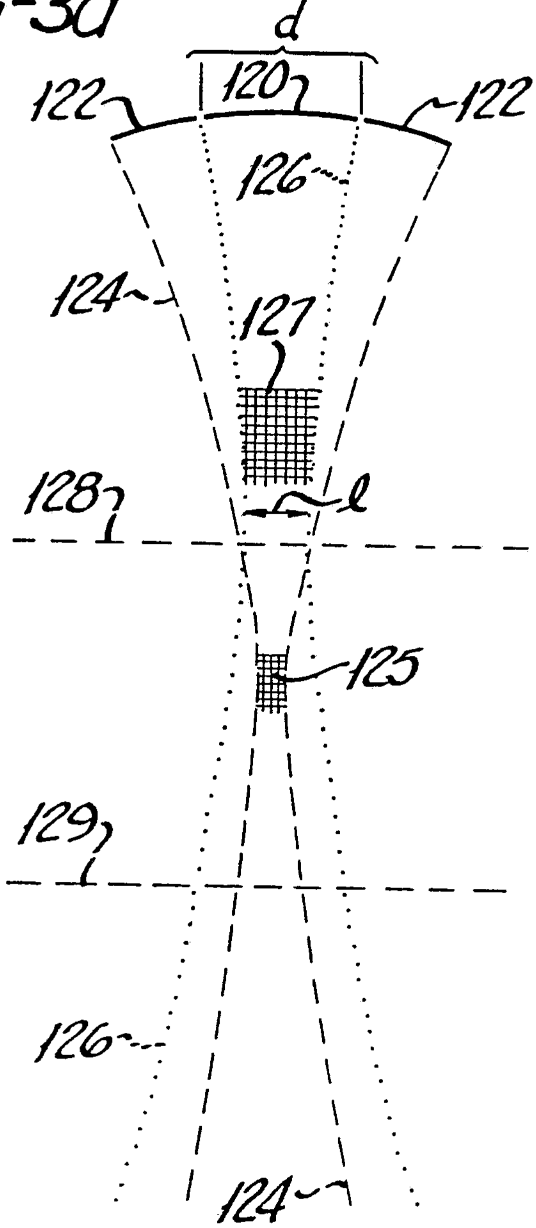

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FIG-3b

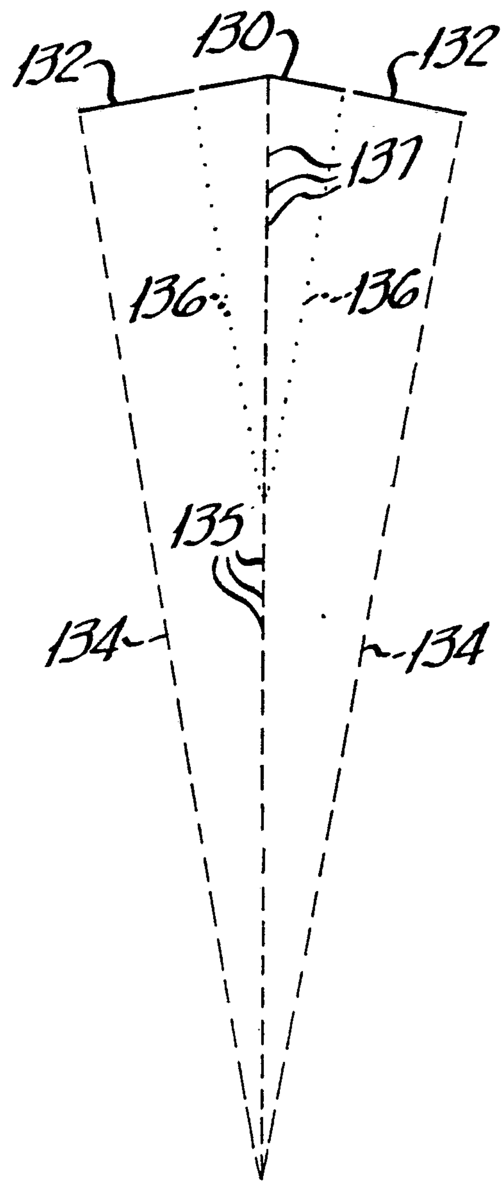
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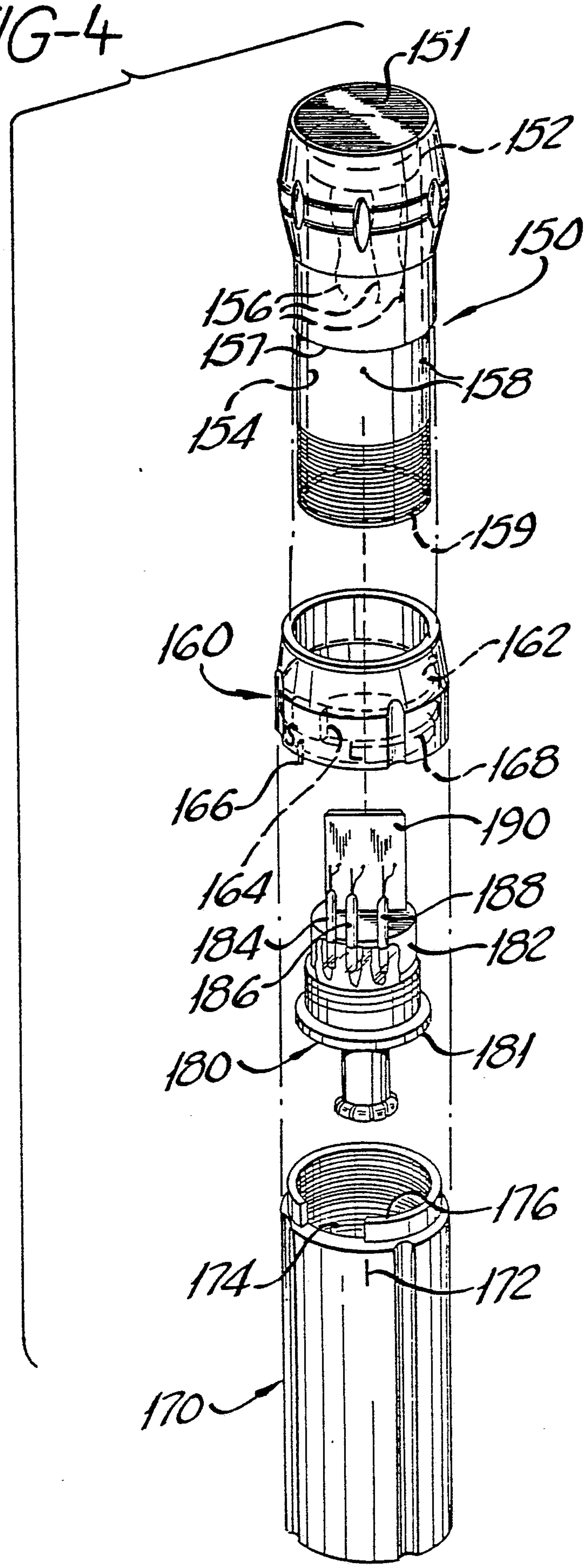
FIG-4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