

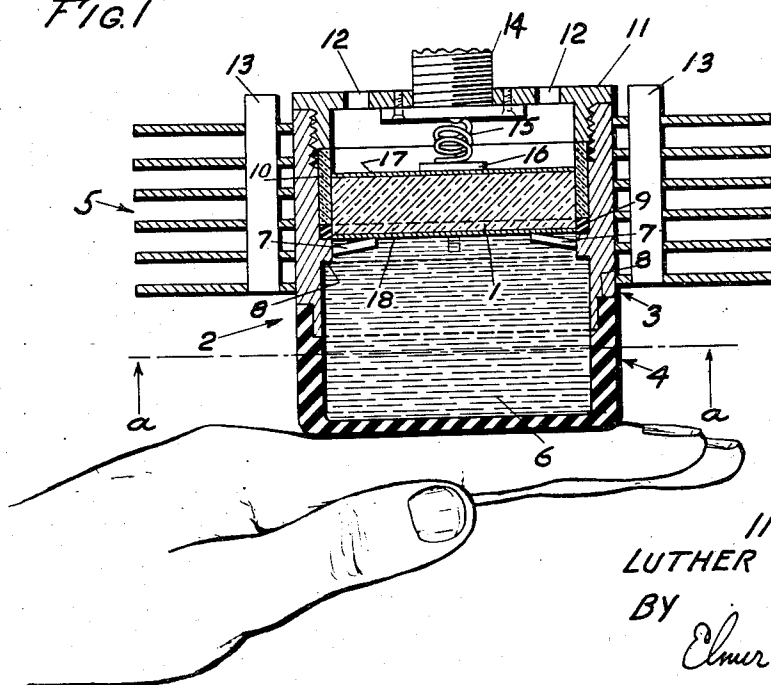
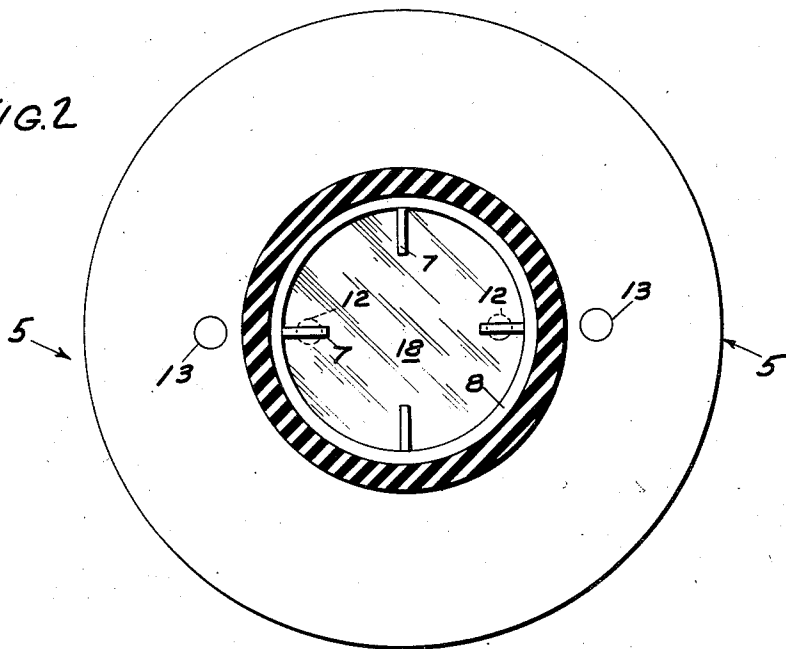
April 23, 1957

L. DAVIS, JR

2,789,557

ULTRASONIC THERAPEUTIC DEVICES

Filed Jan. 7, 1952



INVENTOR
LUTHER DAVIS, JR.

BY

Elmer J. Gorn

ATTORNEY

1

2,789,557

ULTRASONIC THERAPEUTIC DEVICES

Luther Davis, Jr., Newton Highlands, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application January 7, 1952, Serial No. 265,278

4 Claims. (Cl. 128—24)

This invention relates to a therapeutic device for the treatment of living tissue by means of compressional wave energy.

In diathermy treatment of living tissue it is desirable to obtain a uniform distribution of energy over the portion of the tissue to be treated. At or near the surface of a transducer or radiator, localized intensity spots owing to Fresnel diffraction near the radiator create a non-uniform heating or diathermy effect. These Fresnel diffraction intensity spots of the radiator become less pronounced as the distance from the radiator is increased. If a medium to be treated, such as human tissue, is placed adjacent said radiator, the localized intensity spots will create "hot spots" that would burn the tissue and cause serious discomfort. By inserting a layer of liquid, preferably water, of a thickness equal to several wave lengths between the radiator and the medium to be treated, an appreciable distance between said radiator and said medium is furnished, thereby causing the Fresnel diffraction intensity spots to become less pronounced. The layer of liquid is contained in a natural rubber cup or applicator, preferably made of natural rubber, and adapted to contact the portion of the human body to be treated. This applicator is fastened to an enclosed shell, preferably constructed of metal having good heat conducting properties and housing a transducer in the form of a cylindrical disk adapted to vibrate in its thickness direction. Since the liquid and rubber have substantially the same acoustical or wave impedance as the fleshy portions of the human body, there is essentially no reflection at the surface of the applicator when in use and energy losses owing to reflections at the boundaries between the media through which the waves pass are reduced. The rubber applicator, in addition to being of substantially the same wave impedance as human flesh, can also be adapted to readily conform in shape to any desired portion of the human body. An air-cooled jacket surrounding the shell serves to provide adequate cooling. Furthermore, water has low viscosity and high heat capacity and, owing to the convection currents set up within the water by virtue of the compressional waves, water becomes a very effective heat exchanger from the transducer radiator to the air-cooled jacket.

A transmission line, for example, a coaxial line, supplies a voltage of a frequency of from about 50 kc. to several megacycles to the ceramic radiator. Since the ceramic radiator is entirely enclosed in the metal shell, the patient is protected from high voltage; moreover, since the field resulting from the voltage on the radiator is entirely enclosed, broadcast interference resulting from external radiation is prevented.

A ceramic transducer such as barium titanate has high efficiency and hence much lower heat dissipation than magnetostrictive transducers. Moreover, the exciting coils necessary for a magnetostrictive transducer are eliminated, thereby allowing a very compact unit. The ceramic transducer has much lower impedance and hence much lower and safer voltages than transducers using

2

quartz. Finally, the mechanical impedance of a ceramic, such as barium titanate, is much closer to that of the liquid and the tissue than the mechanical impedance of quartz or steel. For this reason a much closer impedance match between ceramic transducer and tissue, with a resulting greater transmission of energy from transducer to tissue, can be obtained with a ceramic transducer.

As previously stated, the transducer is caused to resonate mechanically thickness-wise. Since the transducer is unconstrained in the thickness dimension except by the liquid, a very high efficiency in the thickness vibration mode is attained.

An object of this invention is to provide a therapeutic device using an electromechanical transducer in which the effects of diffraction intensity spots at or near the transducer radiator are considerably reduced.

Another object of this invention is to provide a therapeutic device of improved efficiency and heat dissipation.

A further object of this invention is to provide a medical diathermy device having media whose wave impedance is substantially equal to the wave impedance of living tissue interposed between the radiator and the tissue to be treated.

A further object of this invention is to provide a therapeutic device which prevents external radiation of energy productive of broadcast interference and to prevent shock to the patient resulting from high voltages.

Fig. 1 is a view in cross section of an embodiment of the invention; and

Fig. 2 is a bottom view taken along the line *a-a* of Fig. 1.

Referring to Fig. 1, an ultrasonic transducer head as adapted for use in medical diathermy is shown. A transducer or radiator 1 is placed in a cup 2 formed by an aluminum heat conducting shell 3 cemented to a cap or applicator 4 made of natural rubber. Pure latex has been used for applicator 4 since it is easy to mold and has an acoustical or wave impedance substantially equal to that of living tissue. A form of rubber known as *pc* rubber which has a wave impedance matching that of living tissue may also be used. Cooling fins 5 are soldered or otherwise attached to metallic shell 3 to aid in dissipating the heat generated in the transducer head.

Transducer 1 is a ceramic disk having flat opposed faces and comprising essentially barium titanate permanently poled at high D. C. voltage to act as an electrostrictive transducer. A disk of titanate material can be polarized by connecting a high voltage unidirectional source across the opposite faces; moreover, since titanates are capable of retaining said polarization after removal of the polarizing source, transducer 1 may be polarized prior to mounting in the transducer head. The flat surfaces or faces of transducer 1 are plated with silver. The silver surfaces or electrodes are shown as 17 and 18.

If a voltage is applied to the opposite faces of disk 1, the disk vibrates in the direction of its thickness. These vibrations are forced vibrations and are extremely small, but, as the frequency of the applied voltage coincides with the natural mechanical frequency of the thickness vibration of the disk, resonance occurs and the amplitude of vibration is increased several times. In order to adapt the ceramic disk to resonate mechanically thickness-wise, the thickness is made equal to a half wave length at the operating frequency. For example, at 200 kc., the wave length is approximately one inch since the velocity of propagation of compressional waves in the ceramic is approximately 5,200 meters per second. The disk is, therefore, made one-half inch thick for operation at 200 kc. For operation at one megacycle, a disk one hundred mils thick is used. The diameters of two disks used at 200 kc. and 1 mc. are one inch and two

inches; however, these values are merely illustrative and other disk diameters may be used.

The frequency of operation of the therapeutic device may be at any frequency over a wide range of frequencies. The practical lower limit is about 50 kc. since the dimensions of the device below this limit would have to be unduly large to accommodate the frequency used. If the frequency is over several megacycles, the attenuation of the rubber in the applicator, which increases as the square of the frequency, becomes excessive and the rubber absorbs a considerable portion of the energy radiated from transducer disk 1.

To assemble the transducer head, water 6 which has been distilled and boiled to drive out all of the air therein is poured into the open end of the cup to a level sufficient to insure that there will be no air trapped under the ceramic transducer when the latter is inserted into the cup. Transducer 1 is dropped into the cup and comes to rest against spring contacts 7 which are soldered or otherwise fastened to a shoulder portion 8 of shell 3, as shown in Figs. 1 and 2. Rubber washer 9, which is an adaptation of a seal as used for vacuum work, is dropped into the cup and comes to rest against shoulder 8. A plastic washer or collar 10, having the same external diameter as rubber washer 9, is next inserted in the cup and rests above the rubber washer 9. A metallic end cap 11 is screwed into the threaded end of shell 3 by means of a pair of spanner wrenches (not shown), one of which is inserted in the circular apertures 12 in cap 11. The other spanner wrench may be inserted over rods 13 which are fastened to the fin structure 5, as shown in Fig. 1, thereby preventing shell 3 from turning during the tightening of end cap 11. When cap 11 is tightened, rubber gasket 9 is forced sidewise against the ends of the ceramic transducer disk 1 and the side of shell 3, simultaneously providing a support for the transducer disk and a water-tight seal. The excess water in the upper portion of the cup is drained out through apertures 12. Plastic washer 10 provides voltage insulation from the high voltage electrode of the transducer to the metallic portion of cup 2. A voltage is fed to one side of transducer disk 1 from the center conductor of coaxial fitting 14 through a spring 15 soldered to a flat contact plate 16. The latter is adapted to lie flat against silvered surface 17 of ceramic disk 1. The spring contacts 7, previously described, serve the additional function of grounding the silvered electrode surface 18 of ceramic transducer 1 which rests against the water 6 to the metallic portion 3 of cup 2 and hence to the outer conductor of coaxial fitting 14. The resilient spring contacts 7 give no restraint to the thickness resonance of the transducer.

The complete enclosure of the transducer by grounded metallic shell and end cap provides complete shielding of the transducer and prevents undesirable radiation productive of broadcast interference. The complete enclosure of the transducer also provides adequate protection of the patient against shock owing to the high voltage present. The rubber used in applicator 4, as well as the water 6, has a wave impedance which approximately matches that of living tissue which is to be placed against the applicator. When mechanical waves traveling through a first medium impinge upon a boundary surface separating this medium from a second medium having a different wave impedance, a portion of the energy of the wave is reflected by the boundary surface. By employing media which have substantially identical wave impedances, practically all of the energy radiated can be made to pass through the various media with substantially no reflection at the boundary surfaces. Referring to Fig. 1, inasmuch as water, rubber and living tissue have substantially the same wave impedance, there will be substantially no reflection of energy radiated from transducer 1 at the boundary between the water 6 and the inner surface of rubber applicator 4 or at the boundary

between the outer surface of applicator 4 and the flesh undergoing treatment. A well matched transmission path for the compressional wave energy is thus provided from the transducer 1 through the water and rubber into the body. Oil may be used as a liquid medium instead of an aqueous medium; however, the latter, having lower viscosity and higher heat capacity than oil, provides a better heat exchanging medium than oil and is preferable.

It is desirable that most of the energy will be radiated from the transducer face adjacent the water, so that as much of the wave energy as possible is radiated through the water. The opposite face radiates in air which has a very low wave impedance. The power radiated in air bears the same relation to the power radiated in the liquid as the product ρc for air bears to that for water, where ρ is the density of the medium and c is the velocity of wave propagation in the medium. This ratio is negligible so that most of the energy is radiated from the face adjacent to the water.

While a particular embodiment of this invention has been illustrated and described herein, it is not intended that this invention be limited to such disclosure, and changes and modifications may be made and incorporated within the scope of the claims. For example, the material of which the applicator is made need not be rubber, so long as the wave impedance of said material is substantially equal to that of the living tissue undergoing treatment.

What is claimed is:

1. A therapeutic device for treating living tissue by compressional waves comprising a metallic shell having an internal shoulder portion, an applicator adapted to conform to the tissue to be treated and attached to said shell to form a cup, a plate having electromechanical transducing properties, an elastic electrically insulating washer resting on said shoulder portion of said shell and serving to support said plate and permit free vibration of said plate in the direction of its thickness, and end cap engaging said shell, a coaxial input connector mounted on said end cap and adapted to receive electrical energy from a source, connections from the inner conductor of said connector to one face of said plate, a plurality of metallic spring contacts mounted on the inner periphery of said shell and contacting the opposite face of said plate, said spring contacts and shell providing an electrically conductive path from said opposite face of said plate to the outer conductor of said coaxial connector, and a fluid medium contained within the portion of the cup between said opposite face of said plate and said applicator, said fluid medium and said applicator having wave impedances substantially equal to the tissue to be treated.

2. A therapeutic device for treating living tissue by compressional waves comprising a metallic shell having an internal shoulder portion, a rubber applicator adapted to conform to the tissue to be treated and attached to said shell to form a cup, a plate having electromechanical transducing properties, an elastic electrically insulating washer resting on said shoulder portion of said shell, an insulating collar mounted on said elastic electrically insulating washer, a threaded end cap mounted on the open end of said cup against said collar to force said elastic electrically insulating washer against the sides of said shell and the ends of said plate, said washer serving to support said plate and permit free vibration of said plate in the direction of its thickness, a coaxial input connector mounted on said end cap and adapted to receive electrical energy from a source, connections from the inner conductor of said connector to one face of said plate, a plurality of metallic spring contacts mounted on the inner periphery of said shell and contacting the opposite face of said plate, said spring contacts and shell providing an electrically conductive path from said

5

opposite face of said plate to the outer conductor of said coaxial connector, and a fluid medium contained within the portion of the cup between said opposite face of said plate and said rubber applicator, said fluid medium and said rubber applicator having wave impedances substantially equal to the tissue to be treated.

3. A therapeutic device for treating living tissue by compressional waves comprising a cylindrical metallic shell having an internal shoulder portion, a U-shaped rubber applicator adapted to conform to the tissue to be treated and attached to said shell to form a cylindrical cup, a plurality of heat radiating fins attached to the outer periphery of said shell, a ceramic discoidal element having electromechanical transducing properties and having its opposite faces coated with an electrically conducting material, an elastic electrically insulating washer resting on said shoulder portion of said shell, an insulating collar mounted on said elastic electrically insulating washer, a threaded end cap screwed into the open end of said cup against said collar to force said elastic electrically insulating washer against the sides of said shell and the ends of said element, said washer serving to support said element and permit free vibration of said element in the direction of its thickness, a coaxial input connector mounted on said end cap and adapted to receive electrical energy from a source, connections from the inner conductor of said connector to one coated face of said element, a plurality of metallic spring contacts mounted on the inner periphery of said shell and contacting the opposite coated face of said element, said spring contacts and shell providing an electrically conductive path from said opposite face of said element to the outer conductor of said coaxial connector, and a fluid medium having a thickness equal to several wave lengths at the operating frequency and contained within the portion of the cup between said opposite face of said element and said rubber applicator, said fluid medium and said rubber applicator

6

having wave impedances substantially equal to the tissue to be treated.

4. A therapeutic device for treating living tissue by compressional waves comprising a metallic shell having an internal shoulder portion, an applicator adapted to conform to the tissue to be treated and attached to said shell to form a cup, a plate having electromechanical transducing properties, an elastic electrically insulating washer resting on said shoulder portion of said shell and surrounding the periphery of said plate, resilient electrically conductive means mounted on the inner periphery of said shell and contacting one face of said plate, and a fluid medium contained within the portion of the cup between said opposite face of said plate and said applicator, said fluid medium and said applicator having wave impedances substantially equal to that of the tissue to be treated, said fluid medium further having a thickness of several wave lengths at the operating frequency.

References Cited in the file of this patent

UNITED STATES PATENTS

2,283,285	Pohlman	May 19, 1942
2,430,013	Hansell	Nov. 4, 1947
2,532,507	Meunier	Dec. 5, 1950
2,640,165	Howatt	May 26, 1953

FOREIGN PATENTS

466,212	Great Britain	May 21, 1937
---------	---------------	--------------

OTHER REFERENCES

- Electronic Engineering for September 1950, page 393.
 Copy in Div. 55.
 The Journal of General Physiology, vol. 26, 1942-3, pp. 182-5.
 The Lancet for March 24, 1951, pp. 655-7.
 Copies of these publications in the Scientific Library.