Sept. 21, 1954 W. J. FRY 2,689,947

VARIABLE RESONANT FREQUENCY ULTRASONIC GENERATOR

Filed Sept. 26, 1949

Fig. 1

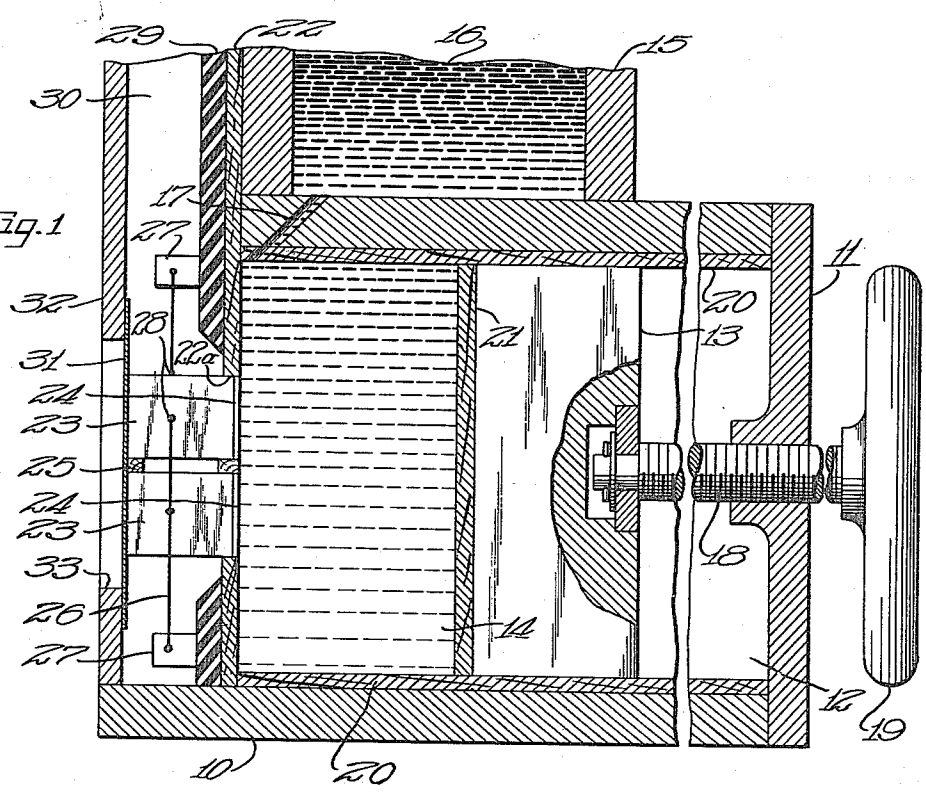
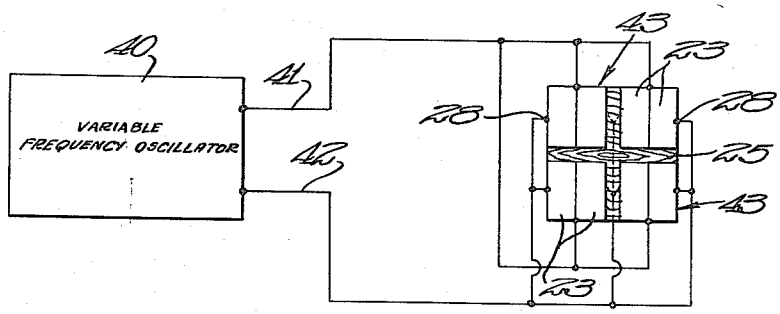


Fig. 2



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Patented Sept. 21, 1954

2,689,947

UNITED STATES PATENT OFFICE

2,689,947

VARIABLE RESONANT FREQUENCY ULTRASONIC GENERATOR

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Application September 26, 1949, Serial No. 117,918

18 Claims. (Cl. 340—10)

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This invention relates to sound wave generators, and more particularly to electrically driven variable frequency ultra-sonic generators.

Experimentation in acoustical phenomena has revealed many useful applications for high intensity sound waves in the frequency range of approximately 25 kilocycles up into the megacycle range which may be radiated into a test medium such as a liquid. Heretofore, devices have been employed which generate a sound wave at a single or several fixed frequencies in this ultra-sonic range, but of far greater usefulness would be a device capable of radiating sound waves of variable but controlled frequencies in this same range.

Accordingly, an object of this invention is to provide a sound wave generator which is capable of controlled variation in the frequency of the generated wave.

Another object of this invention is to provide an ultra-sonic generator utilizing an electro-mechanical coupling material coupled to a mass in such a way that the system comprising the material and the mass may be caused to resonate at selected varying frequencies.

Another object of this invention is to provide an ultra-sonic generator which is characterized by an electrically driven electro-mechanical coupling material coupled both to a sound output chamber and to a mass of variable dimensions.

Another object of this invention is to provide an apparatus using one or more piezo-electric crystals to convert electrical energy into mechanical vibrations along a range of frequencies.

Another object of this invention is to provide a piezo-electric crystal coupled to a mass to form an acoustic system such that the resonant frequency of this system may be varied by varying the dimensions of the mass.

Still another object of this invention is to provide a plurality of piezo-electric crystals in parallel electrical connection and suitably mounted for coupling with a mass which is acoustically insulated from its container or support.

Another object of this invention is to provide an ultra-sonic generator which utilizes a piezo-electric crystal coupled to a liquid column to form an acoustic system the resonant frequency of which may be continuously, controllably and accurately varied.

Another object of this invention is to provide a sound chamber including a membrane bonded to a piezo-electric crystal which, in turn, is coupled to a column of liquid such that the sound wave produced by the crystal of a frequency dependent on the mass of the liquid may be transmitted through the membrane and localized to the sound chamber.

In accordance with the general features of this invention, one or more piezo-electric crystals are intimately coupled with a volume of liquid

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mercury filling a box-like container which is extensible in one dimension. The piezo-electrical crystals are driven in parallel electrical connection by a variable frequency electric power supply such as an oscillator. By utilizing a close-fitting piston and a reservoir of mercury to keep the container filled, the volume of mercury is allowed to change only in one dimension. A composite vibratory system is thereby obtained, the resonant frequency of which is diminished by extension of the variable dimension of the mercury.

Other objects and features of the invention will become apparent to those skilled in the art from the following detailed description taken in connection with the accompanying drawings, in which but a single embodiment is illustrated.

On the drawings:

Figure 1 is a vertical sectional view of the ultra-sonic generator and one face of a sound chamber coupled thereto.

Figure 2 is a schematic diagram of the electrical circuits for the ultra-sonic generator, with the mounted crystals in side elevation.

As shown on the drawings:

The reference figure 10 indicates generally a supporting structure which together with an end plate 11 forms a container 12 of generally box-like configuration. This container 12 houses a close-fitting but slidable piston 13 and a volume of mercury 14, or other suitable fluid mass of low acoustic absorption, acting against the piston 13. Above this container 12 is a reservoir 15 with a reverse supply of mercury 16 to keep the container 12 filled with mercury. An interconnecting conduit 17 is provided for this purpose.

The piston 13 which limits the volume of the mercury 14 is driven by a screw shaft 18 threaded through the end plate 11 to adjustably fix the volume of mercury. Exterior to the container 12, the shaft 18 is provided with a hand wheel 19 for manually adjusting the position of the piston.

To acoustically insulate the mercury 14, a layer of acoustically insulating material 20, such as balsa, is affixed to the inner walls of the chamber 12 and to the end face 21 of the piston 13. The insulating material should preferably be one not wettable by mercury. Balsa wood is the preferred insulating material, although other cork-like materials also find use for this purpose.

The end of the chamber 12 opposite the end plate 11 is partially closed by an end sheet 22, also of acoustically insulating material, such as balsa. A square aperture 22a, centered with respect to the adjacent face of the mercury 14, is provided in the end sheet 22 for the mounting of a plurality of piezo-electric crystals 23. The

material and cut of the piezo-electric crystals is selected in accordance with the frequency range to be covered. At lower ultra-sonic frequencies, a 45° Z-cut bar of ammonium dihydrogen phosphate crystal has been found to give good results. In general, a crystal with a high coefficient of electromechanical energy transference is desirable. This coefficient defines the ratio of sound output to the electric field strength applied to the crystal.

A second determinant in the choice is the frequency range desired, that is, at low ranges it is desirable to have a crystal vibrating in the longitudinal mode, and at high frequencies it is desirable to have a crystal vibrating in the thickness mode.

The crystals 23 are coupled to the mercury 14 through adhesively bonded plates 24 of a material such as a silver-palladium or gold-palladium alloy in solid solution form which is susceptible of being wetted by mercury yet not subject to attack by the mercury, nor capable of being appreciably dissolved therein. The percentage of palladium in the alloy should be low enough to permit amalgamation, but high enough to prevent appreciable deterioration by the mercury. To prevent the mercury from amalgamating with the surface of the alloy to be adhesively bonded to the crystal, such surface is preferably coated with a metal, such as nickel, which does not amalgamate with mercury. An especially preferred alloy is one containing 40% palladium and 60% silver.

These plates 24 and the adhesive must have a low acoustic absorption coefficient to allow ready transfer of acoustic energy through their thickness. The crystals 23 are most conveniently mounted in pairs which are spaced apart by cross-like spacers 25 of a material such as balsa, so as to allow a substantial air space between adjacent pairs of crystals. It is necessary to avoid mutual acoustic coupling between crystals to permit a wide variation in the output frequency. For example, a 4-crystal unit, with the crystals mounted with air spaces between them and supported by a balsa mount, will give 2 to 1 shifts in resonant frequency if the mercury column cross-section is twice the cross-section of the multiple crystal unit. If, however, the same crystals are fastened rigidly together by an adhesive, having no air space between them, and are mounted on the same size mercury column, a maximum shift in frequency on the order of 15% is obtained.

The crystals 23 are supplied with power through leads 26 supported by terminals 27 and fastened to the crystals at electrodes 28. The terminals 27, in turn, are supported on insulating sheets 29 which back the end facing 22. A free air chamber 30 surrounds the crystals 23 at their lateral faces.

The limit of the air chamber is defined by a wall 32 having an aperture 33 therein. The aperture 33 is closed by means of a flexible membrane 31 in abutting contact with the ends of the crystals 23, to couple the vibrating motion to the air, water, or other ambient medium in which the apparatus is disposed.

Figure 2 illustrates schematically the wiring diagram for an apparatus according to the present invention having four sets of multiple crystal units 23 of two crystals each. A variable frequency oscillator 40 has its output leads 41 and 42 connected across a multiple array of crystal units 43, each of the units 43 being composed of two crystals 23, joined at their interface with a suitable adhesive. As shown, the crystals 23 are driven in parallel from the oscillator 40. The crystals are matched so that their natural resonant frequencies are substantially equal, and represent a frequency in the upper portion of the range to be covered by the unit.

The operation of the apparatus is as follows. The oscillator is first adjusted to the frequency to be transmitted. Next, the displacement of the piston 13 is adjusted by operation of the hand wheel 19 until the maximum amount of power is produced at membrane 31 for the medium to which the vibrations are to be coupled.

From the foregoing, it will be observed that I have herein provided a variable frequency ultrasonic generator which is extremely flexible in operation, has very low losses, and is capable of producing vibrations over an extended range of frequencies.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

I claim as my invention:

1. In an ultra-sonic sound wave generator driven by a variable frequency electric power supply, a piezo-electric crystal driven by said supply, a rigid container, liquid mercury filling the same, a piston forming an adjustable wall for said container, means for acoustically decoupling said mercury from said container, a coupling plate bonded to said crystal, said plate being wetted but not deteriorated by said mercury to intimately couple and thereby form an acoustical system comprising said crystal and said mercury, means for adjusting the position of said piston to accurately vary one dimension of said mercury and thereby to vary the resonant frequency of said system, and a mercury reservoir connecting with and filling said container.

2. In an ultra-sonic wave generator deriving electric power from a variable frequency supply and including a piezo-electric crystal driven by said supply, a container having an adjustable wall, and a fluid of low acoustic absorption filling said container, the improvement comprising a plate bonded to said crystal and wetted but not deteriorated by said fluid to intimately couple and thereby form a composite acoustic system comprising said crystal and said fluid, whereby adjustment of the wall varies substantially the resonant frequency of said system.

3. In an ultra-sonic wave generator deriving electric power from a variable frequency supply and including a piezo-electric crystal driven by said supply, a container having an adjustable wall, and a fluid filling the container, the improvement comprising a plate bonded to a face of said crystal and wetted but not deteriorated by said fluid to intimately couple and thereby form a composite acoustic system comprising said crystal and said fluid, whereby adjustment of the wall varies substantially the resonant frequency of the system, means not wetted by said fluid for acoustically decoupling said system from said container, and a membrane in contact with a second face of said crystal to transmit a localized sound output of said system.

4. In an ultra-sonic wave generator energized by a variable frequency electric power supply, a plurality of piezo-electric crystals driven by said supply, a natural resonant frequency of said crystals being matched at a frequency in the upper region of a predetermined range, a con-

tainer having an adjustable wall, a fluid which does not wet said crystals filling said container, a plate bonded to each of said crystals and wetted but not deteriorated by said fluid to intimately couple and thereby form a composite acoustic system comprising said crystals and said fluid, whereby adjustment of said wall varies substantially the resonant frequency of the system, insulation means including spacers between said crystals not wetted by said fluid for acoustically decoupling said system from said container, and a membrane contacting each of said crystals to transmit a localized sound output of said system.

5. In an ultra-sonic wave device including a piezo-electric crystal, a fluid capable of supporting acoustic waves which does not wet said crystal, and a container supporting said fluid adjacent to said crystal, the improvement comprising a plate bonded to said crystal and wetted but not deteriorated by said fluid to intimately couple and thereby form an acoustic system comprising said crystal and said fluid.

6. In an ultra-sonic wave device, a piezo-electric crystal, a mass having a variable dimension, acoustic insulation means for supporting said mass and said crystal, means for coupling said mass intimately to said crystal to form a composite vibratory system, and means for varying said dimension of said mass to vary the resonant frequency of said system.

7. In an ultra-sonic wave device, a plurality of piezo-electric crystals bonded together in pairs, said pairs being mutually spaced and insulated, a column of liquid of variable length, means coupling said column intimately with corresponding faces of said crystals to form a composite vibratory system, a flexible membrane contacting corresponding opposite faces of said crystals to transmit a localized sound output from said system and means for varying said length of the liquid column to vary the resonant frequency of said system.

8. In an ultra-sonic wave device, a member having a resonant frequency in the ultra-sonic range, an acoustically conductive mass of variable dimension, means intimately coupling said mass to said member to form a composite vibratory system, means including a membrane actuated by said member to receive and localize the output of said device, and means for varying a dimension of said mass to vary the resonant frequency of the composite system.

9. In an ultra-sonic wave device, a piezo-electric crystal, a body of acoustically conductive fluid, means coupling said body to said crystal to form a composite vibratory system, and an insulating container for said fluid body not wetted thereby and having a movable wall to vary a dimension of said fluid body, thereby to vary the resonant frequency of the composite system.

10. In an ultra-sonic wave device, a piezo-electric crystal having a resonant frequency in the ultra-sonic range, an acoustically conductive fluid mass, means coupling said crystal to said fluid mass, said fluid mass wetting a face of said means to form a composite vibratory system, a flexible membrane coupled to said crystal to receive and localize the output of the acoustic system, and means for varying a dimension of said fluid mass to vary the resonant frequency of the composite system.

11. In an ultra-sonic wave device, a piezo-electric crystal, a liquid of low acoustic absorption coupled to one face of said crystal through means wetted but not deteriorated by said liquid to form a composite vibratory system, and electrodes in contact with opposed surfaces of said crystal adjacent said face to conduct energizing current thereto.

12. In an ultra-sonic wave generator, a member having a resonant frequency in the ultra-sonic range, a liquid mass of low acoustic absorption, means coupling said mass to a face of said member, a membrane abutting an opposite face of said member for receiving and localizing the output of the generator, and electrodes in contact with some of the remaining opposed faces of said member.

13. In an ultra-sonic wave generator, a mass of dimensionally variable low acoustic absorption material, acoustic insulation means for supporting said mass for dimensional variation, a piezo-electric crystal having a face acoustically coupled to said mass by means intimately coupling said crystal and said means, a membrane abutting the opposite face of said crystals acoustically coupled to said crystal to transmit a localized sound output from the generator, and electrodes affixed to opposed free faces of said crystal to impress electric power thereupon, causing said membrane to broadcast vibrations dependent on the dimensions of said mass.

14. In an ultra-sonic wave device, a piezo-electric crystal and a coupling plate composed of silver-palladium alloy bonded to a face of said crystal to intimately couple said piezo-electric crystal to a mass of variable dimension.

15. In an ultra-sonic wave device, a piezo-electric crystal and a coupling plate composed of a gold-palladium alloy bonded to a face of said crystal to intimately couple said piezo-electric crystal to a variable dimension mass.

16. In combination, a member adapted to vibrate at ultrasonic frequencies, a body of fluid intimately coupled to one face of said member, means lying between said member and said fluid intimately coupling said member and said fluid, and energizing means to cause said member and said fluid to vibrate as a complete ultrasonic acoustic system.

17. In combination, a piezo-electric crystal, means bonded to said piezo-electric crystal on one face thereof, a body of mercury in intimate contact with said means and there by intimately coupled to said crystal, and energizing means for causing said crystal and said body of mercury to vibrate at ultrasonic frequencies as an acoustic system.

18. A variable frequency ultrasonic generator comprising, in combination, a supporting structure, a piezo-electric crystal supported by said supporting structures, means defining a liquid reservoir with said crystals, a body of mercury in said reservoir, means intimately coupling said body to one face of said crystal, means for applying an alternating voltage of ultrasonic frequency to said crystal, thereby to effect unitary vibrations of said crystal and said mercury, and means for varying a dimension of said body of mercury, thereby to change the frequency at which said vibrations occur.

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