SS REFERENCE SEARCH ROOM
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Aug. 28, 1956 E. B. HANSELL 2,761,076

ULTRASONIC GENERATOR AND CRYSTAL HOLDER

Filed Aug. 10, 1951 3 Sheets-Sheet 1

Fig. 1.

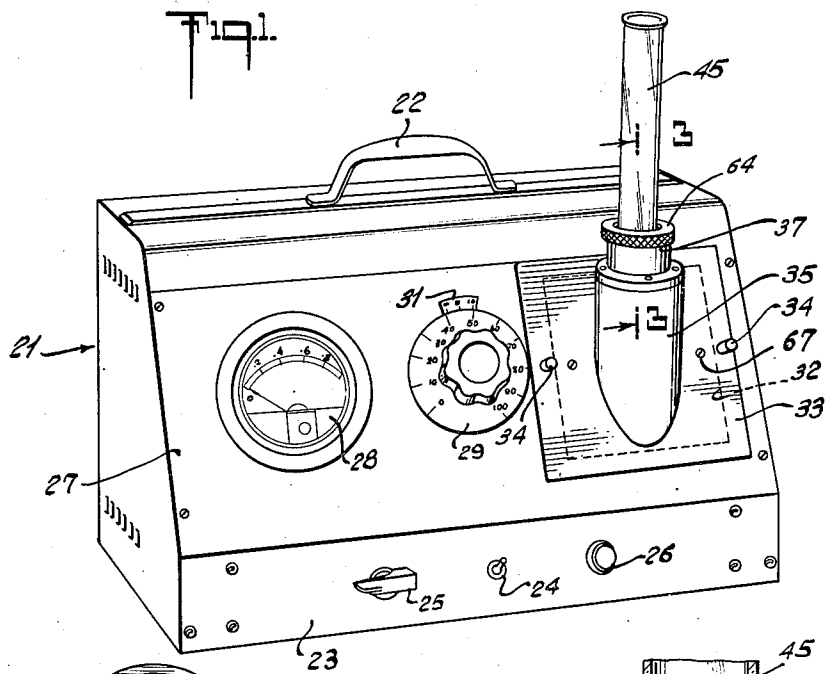


Fig. 2.

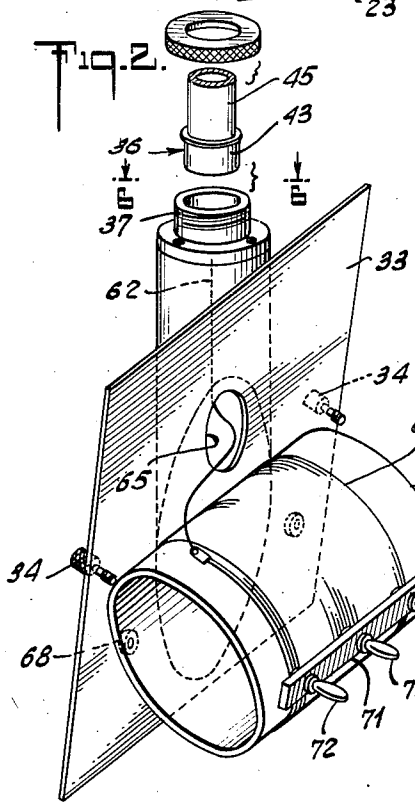
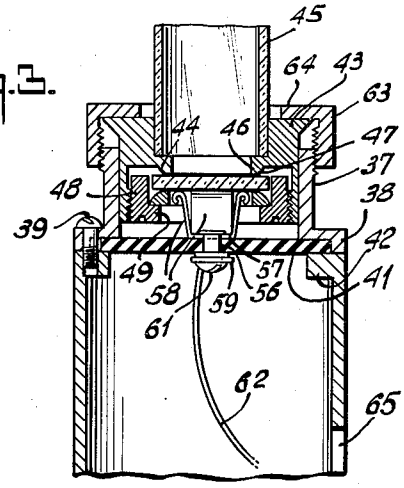
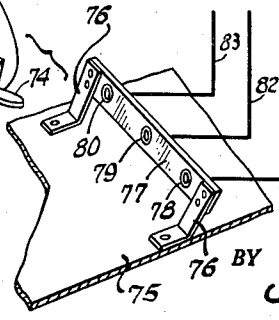


Fig. 3.





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Fig. 4.

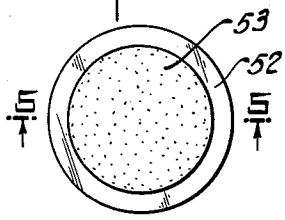


Fig. 5.

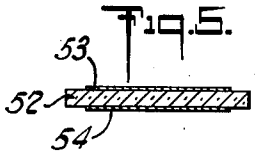


Fig. 6.

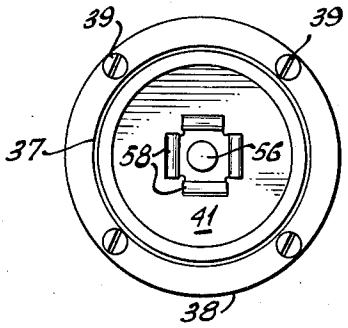


Fig. 7.

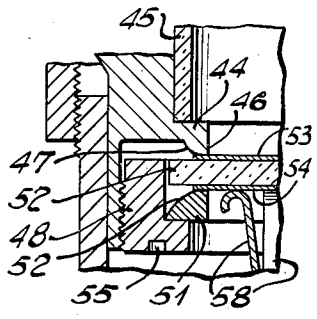


Fig. 8.

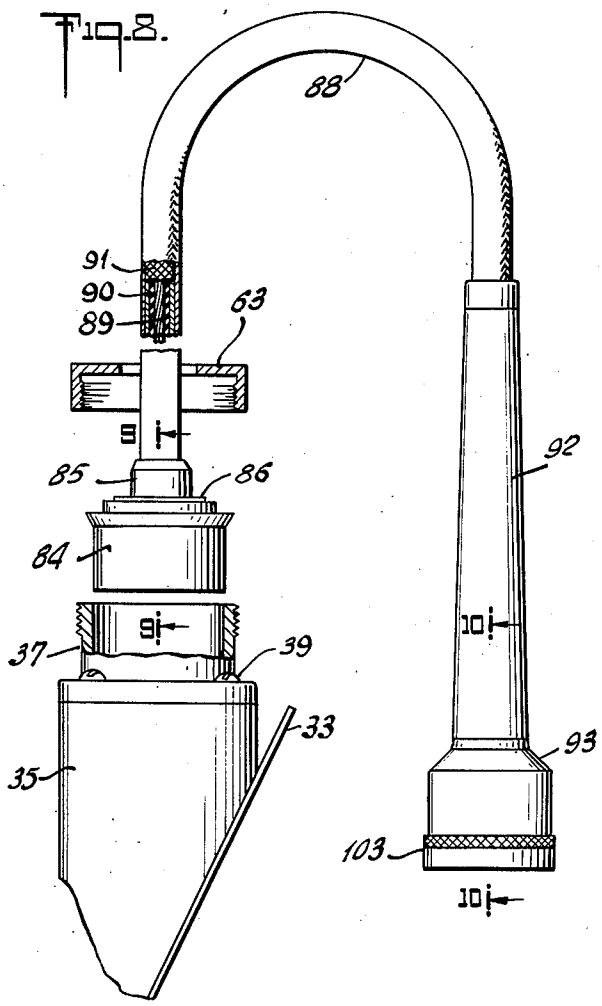


Fig. 9.

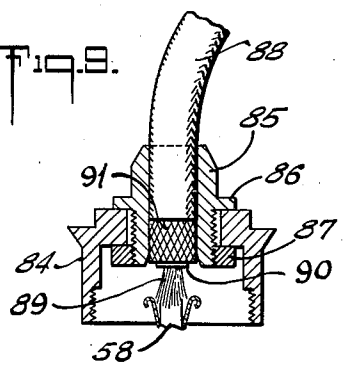
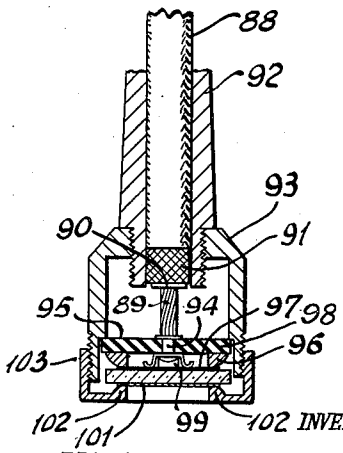


Fig. 10.



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ULTRASONIC GENERATOR AND CRYSTAL HOLDER

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Fig. 11

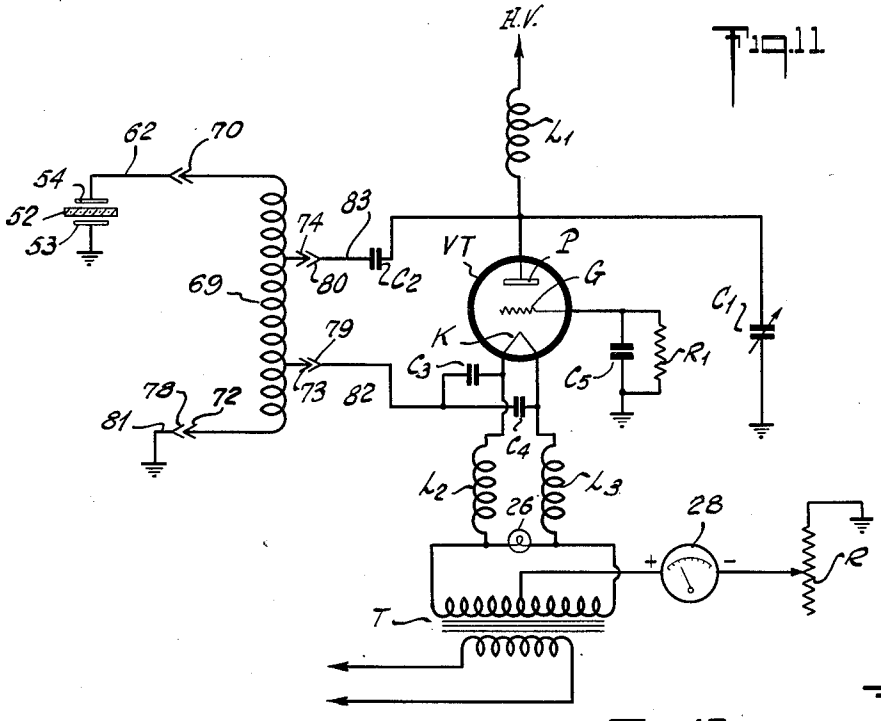


Fig. 12.

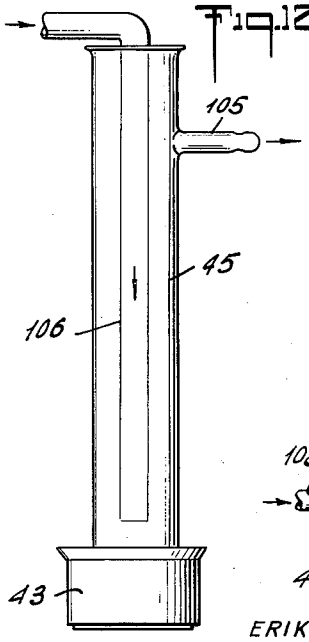


Fig. 13.

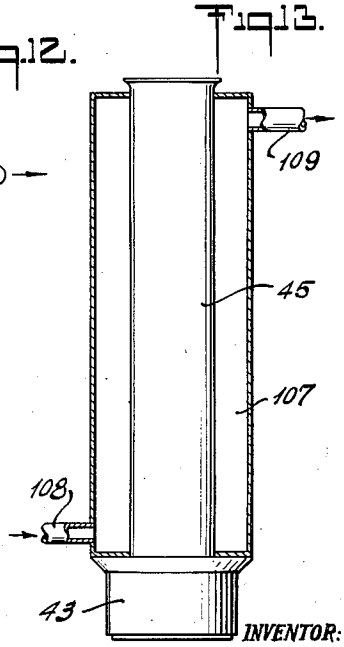
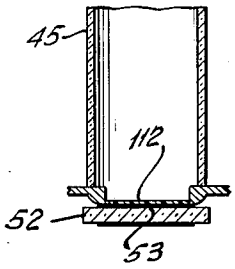


Fig. 14.



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2,761,076

ULTRASONIC GENERATOR AND CRYSTAL HOLDER

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Application August 10, 1951, Serial No. 241,314

2 Claims. (Cl. 310—9.1)

This invention relates to ultrasonic generators and transducers operated thereby and more particularly to an ultrasonic instrument which combines an ultrasonic generator with a novel crystal holder-reaction chamber unit in a single cabinet.

It has been established that the factor that limits the power output of piezoelectric transducers, and particularly transducers made of crystal and quartz, is not the mechanical strength of the crystal but is rather the requisite minimum dielectric strength at the edges of the electrodes necessarily associated with the crystal. It had been found that arcing and corona formation at the electrode edges on the piezoelectric crystal caused the crystal to be fractured or to exhibit other short-life characteristics. In the past the dielectric strength of the crystal transducer at these electrode edges has been increased by covering crystal transducers with a suitable insulating oil. Although this practice prolongs the life of the crystal, it is unsatisfactory in many applications due not only to the cumbersomeness and complexity of providing a transformer oil bath, but also due to concomitant attenuation of energy that is inherent in any attempt to transmit ultrasonic vibrations through the transformer oil and through the walls of a reaction vessel immersed in the transformer oil.

The present invention obviates these difficulties by providing a novel crystal holder which reduces the possibility of arcing or corona formation at the electrode edges on the crystal whereby the makeshift of using transformer oil is dispensed with. By means of the present invention the material to be treated by ultrasonic vibrations may be placed directly in contact with the vibrating crystal thereby coupling the greatest possible amount of energy into the material to be treated. Because of the novel features of this crystal holder it is now possible to combine the crystal holder and reaction vessel into a single replaceable unit which can be incorporated into the cabinet of an ultrasonic generator thereby making a unitary instrument that is truly portable.

An object of the invention is to provide a combination crystal holder and reaction vessel wherein the material to be treated by ultrasonic vibrations is in direct contact with the vibrating crystal thereby obviating attenuating characteristics of previous instruments.

Another object of the invention is to incorporate the aforementioned crystal holder-reaction vessel as a replaceable unit into a cabinet containing the ultrasonic generator to produce a truly portable machine.

Another object of the invention is to provide a crystal holder designed to eliminate arcing or corona discharge at the electrode edges of the piezoelectric transducer without using transformer oil.

Another object of the invention is to provide a crystal holder-reaction vessel wherein accessory transducing media are eliminated thereby reducing reflections and losses of vibrational energy.

Another object of the invention is to provide a piezoelectric crystal holder which permits increased voltage to be applied across the crystal thereby making possible a greatly increased power output from the transducer.

A further object of the invention is to provide an ultrasonic generator and crystal-holder assembly wherein the crystal-holder can be conveniently replaced when it is desired to change crystals in order to operate at different frequencies.

A still further object of the invention is to provide a crystal-holder probe which can readily be attached to the generator cabinet.

These and other objects of the invention will be best understood from the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a perspective view of the cabinet of the ultrasonic generator incorporating the improved crystal holder-reaction vessel of the invention;

Figure 2 is an enlarged rear perspective view of the removable panel section of the cabinet in Figure 1, shown partly in phantom outline and partly exploded together with a broken away schematic showing of the manner in which the coil member is connected to the generator circuit;

Figure 3 is an enlarged cross-section view taken on line 3—3 of Figure 1;

Figure 4 is an enlarged top elevation of the piezoelectric crystal;

Figure 5 is a section view taken on line 5—5 of Figure 4;

Figure 6 is an enlarged top view taken on line 6—6 of Figure 2;

Figure 7 is a greatly enlarged fragmentary view of a portion of Figure 3;

Figure 8 is an enlarged view, partly exploded and broken away, of a probe crystal holder attached to the panel structure of the cabinet of Figure 1;

Figure 9 is a section view taken on line 9—9 of Figure 8;

Figure 10 is a section view taken on line 10—10 of Figure 8;

Figure 11 is a schematic diagram of the ultrasonic generator circuit contained within the cabinet of Figure 1 and incorporating the piezoelectric crystal;

Figure 12 is a side view of another form of reaction chamber;

Figure 13 is a side view, partly in cross-section showing a modification of the reaction vessel together with a cooling jacket; and

Figure 14 is a cross-section of a portion of the reaction chamber showing a protective arrangement for the piezoelectric crystal.

Referring now to the drawings, Figure 1 shows a cabinet generally designated 21, made of suitable sheet metal and having a handle 22 which permits the cabinet to be carried about from one place to another. Cabinet 21 contains an electronic ultrasonic generator circuit. The front of the cabinet has a lower horizontal panel 23 on which there is positioned a manual on-off switch 24, a power control knob 25 to vary the acoustic power output from zero to the maximum specified, and an on-off pilot light 26 which visually indicates whether or not the generator is in operation.

The upper portion of the front of the cabinet has a rearwardly sloping panel 27 on which there are placed a meter 28 calibrated in milliamperes to indicate the acoustic power output, and an ultrasonic tuning control 29 having a series of arbitrary scale graduations from zero to 100. A zero setting plate 31 is arranged to provide a point of reference for the readings on the turning control so that data may be recorded and experiments repeated under control and observed conditions.

On the right hand side of panel 27 is a large aperture represented by the dotted outline 32 which is covered by a removable panel plate 33. Plate 33 is secured in position on panel 27 by means of screws 34 which

engage suitable nuts or screw holes in appropriate brackets (not shown) attached to the underside of panel 27. Secured to or molded to the front of plate 33 is a cylindrical support member 35 which forms the base for the transducer unit, generally designated 36, shown in Figure 2 and in enlarged cross-section in Figure 3.

The crystal holder, generally designated 36, is housed in a cylindrical member 37 having an annular collar 38 which is secured to support member 35 by means of screws 39. Member 37 has a recessed shoulder which accommodates an insulator plate 41 which is firmly held against annular collar 42 of support member 35.

The crystal holder 36 comprises a bushing 43 having a central aperture whose diameter is narrowed by a shoulder 44. Seated within said aperture and upon annular shoulder 44 is a glass tube 45 which may be permanently cemented into the bushing and which serves as a reaction chamber. The portion of bushing 43 below shoulder 44 projects downward in the form of a ring 46 having a flat inside periphery and a rounded shoulder 47 which curves outward and upward. It will be noted that ring 46 is machined as an integral part of bushing 43 which is maintained at ground potential. Ring 46 may alternatively be a separate element held in the same position.

The lower portion of the central aperture of bushing 43 is wider than the upper portion and is partly threaded to accommodate an internal threaded bushing 48. Bushing 48 has an annular shoulder 49 upon which ring 51 is supported. The upper shoulder 52 of ring 51 curves outward and downward away from the internal periphery of said ring to its outer periphery in the opposite direction of the curvature of shoulder 47 of ring 46.

Held firmly in position between ring 46 and ring 51 is a piezoelectric crystal 52 made of quartz, barium titanate or the like, with a thin metallic electrode 53 vapor deposited or otherwise bonded on the upper face of the crystal and a similar electrode 54 bonded on the lower face of the crystal. See Figures 4 and 5. It will be noted that the peripheral edges of both electrodes 53 and 54 terminate substantially at the points where they are contacted by rings 46 and 51, respectively.

Due to the necessary thinness of the plating, which may be of the order of one-half of a ten thousandths of an inch, and which are drawn disproportionately enlarged for purposes of clarity in Figures 3, 7, 10 and 14, the edges of electrodes 53 and 54 may be considered similar to knife edges. The sharp discontinuity of the edge of the plating is well known to be conducive to the formation of corona effects due to the high electrical potentials and the low dielectric strength at the sharp edges which result in breakdown of the crystal without regard for its mechanical strength.

Where before the dielectric strength at the electrode edges has been increased by covering them with a suitable insulating oil, such as transformer oil, the present invention obviates this unsatisfactory practice by means of rings 46 and 51 whose contacting surface rests at or very near the peripheral edges of the respective electrodes with the outer peripheral surface of the rings curving away gently outward from said edges and away from the surface of the crystal. By virtually changing the profile of the electrode edges to a substantially smooth curved contour extending away from the piezoelectric crystal, conditions conducive to the formation of corona are minimized or substantially eliminated.

In other words, the rings are so designed that they minimize the sharp discontinuities in the voltage gradient of the edges of the crystal electrodes to the low potential side of the system. Thus the possible voltage which can be applied across the crystal is greatly increased, thereby making possible a greatly increased acoustic power output from the transducer.

It is now possible to bring the material to be treated by ultrasonic vibrations directly in contact with the vibrating crystal, since the need for various transducing media, such as transformer oil, which would otherwise result in reflections and losses in energy is eliminated. Not only is the crystal now capable of producing a higher power output, but the material to be treated, being in direct contact with the crystal, separated only by the thin electrode, can now absorb a greater amount of energy. This arrangement also makes it possible to provide transducer assemblies that are more suitable for experimental work.

Although crystal 52 and electrodes 53 and 54 are illustrated in Figure 4 as being circular in form, it is understood that other shapes of crystals and electrodes may be used with appropriate changes in the form and dimensions of rings 46 and 51 to cooperate with said electrodes.

Key holes 55 are provided to accommodate an appropriate tool for tightening and turning bushing 48 within bushing 43, both for securing the crystal in position and for removing it when necessary.

In the center of insulator plate 41 is a stud 56 to the top of which is connected a spider 57 having curved spring plates 58 which extend upwardly to contact electrode 54 whereby the high potential is brought to crystal 52. A top view of spider 57 is shown in Fig. 6. Connected to the lower end of stud 56 is a lug 59 held in position by screw 61, said lug serving as a terminal which lead line 62 connects to the generator circuit within cabinet 21.

Bushing 43 is slidably inserted into cylinder 37 and is secured in position by threaded ring 63 whose shoulder 64 bears down upon the top surface of said bushing when said ring is threaded upon the outer threaded periphery of cylinder 37. Ring 63 has a central aperture through which cylinder 45 passes freely.

Plate 33 has an aperture 65 which communicates with the hollow interior of support member 35. (See Figs. 1 and 2.) A cylindrical form 66 is attached to the rear of plate 33 by means of screws 67 and nuts 68. A plurality of turns of wire are wound around form 66 to constitute a coil 69 whose electrical impedance is arranged to match the frequency of crystal 52.

Lead line 62 is electrically connected by means of a jack (not shown) to one end of coil 69. A bar 71 of insulating material is attached over coil 69 to form 66, and carries male jack plugs 72, 73 and 74, each of which are tapped to different points of coil 69.

A floor portion 75 is built up inside cabinet 21 behind panel 33 as shown in the angularly exploded partially cut away portion of Fig. 2. Positioned on floor 75 are two brackets 76 which support a bar 77 having female jack plugs or sockets 78, 79 and 80 adapted to accommodate male plugs 72, 73 and 74, respectively, when plate 33 with its attached crystal holder and coil is placed in position in cabinet 21. Lead lines 81, 82 and 83 are attached to plugs 78, 79 and 80, respectively, for connection to the generator circuit shown in Fig. 11.

It will be noted that plate 33, coil 69 and the transducer and reaction vessel assembly mounted on support member 35 form a replaceable unit that can easily be inserted in or removed from the generator cabinet 21. Since a crystal of a particular thickness operates at its natural frequency with a matching impedance coil, when it is desired to change the crystal in order to treat materials at different frequencies, it is also necessary to change the matching impedance coil which must necessarily be associated with each crystal. Thus the arrangement of the crystal and coil assembly upon a replaceable panel portion enables the ultrasonic instrument of the present invention to be adapted for operation at different frequencies. All that is necessary is to have several replaceable panel units wherein crystal and coil are matched to operate at specified frequencies.

The generator circuit producing electrical oscillations for causing the piezoelectric crystal to vibrate mechanically consists of a so-called self-rectifying Hartley oscillator having a grounded grid which has the advantage of great stability, freedom from "hand effects" since the low end of the tuning condenser is at ground potential.

The oscillator generator comprises a vacuum tube VT having a cathode K, grid G and plate P. Plate P is connected through radio frequency choke L1 to a power supply HV. Connected between plate P and ground is a variable tuning condenser C1 which is operated by tuning control **29** on the panel of the cabinet. Plate P is also connected by way of blocking condenser C2 and jacks **74** and **80** to a suitable point on coil **69**.

Heater supply for cathode K is provided by transformer T connected to a suitable power source. Connected to a center tap on the secondary of transformer T is a plate current milliameter **28** previously described in connection with Fig. 1. A power control rheostat R is connected to meter **28** and is operated by power control knob **24** on the front of the cabinet. The secondary of the transformer is connected to the two leads to cathode K through radio frequency chokes L2 and L3, respectively. Cathode K is also connected by way of feedback coupling condensers C3 and C4 and jacks **73** and **79** to a suitable point on coil **69**. A pilot light **26** (see Fig. 1) is connected between the cathode leads in order to indicate on the front of the cabinet whether or not the generator circuit is operating.

Grid G is connected to a grid leak resistor R, which is bypassed by a radio frequency condenser C5. One end of coil **69** is connected through jack **70** and lead line **62** to electrode **54** on one face of crystal **52**. Electrode **53** on the other face of crystal **52** is connected to ground to complete the circuit through said crystal. The other end of coil **69** is connected to ground by way of jack plugs **72** and **78** and lead line **81**.

The instrument of the present invention also provides for a probe attachment that can readily be connected to support member **35** as shown in Fig. 8. Ring **63** is unscrewed and crystal holder **36** containing crystal **52** and its attached tube **45** is removed. In its place an adapter bushing **84** is inserted into member **37**.

Adapter bushing **84** has a top central aperture through which a collet **85** is inserted. See Fig. 9. Collet **85** is free to rotate in said aperture but has a pair of annular flanges **86** and **87** which serve to maintain collet **85** in position. Inserted through collet **85** is a flexible coaxial cable **88** having an inner conductor **89** separated by insulator **90** from outer conductor **91** as shown at the broken away section of the cable in Fig. 8.

The insulation on the outside of cable **88** extends part way into collet **85** but it is peeled away to expose the outer conductor **91** which establishes electrical contact with collet **85** which is grounded through bushing **84**, member **37**, member **35** to cabinet **21**.

Inner conductor **89** is exposed at the end of cable **88** and is arranged to come in contact with spider leaves **58** which were described above in connection with Figs. 3, 6 and 7.

The other end of cable **88** is encased in a suitable handle member **92** while the end of the cable projects into the central aperture of collet **93**, Fig. 10. Here also the outer insulation has been partly stripped away so that electrical contact is made between the outer conductor **91** and collet **93**.

The inner conductor **89** of cable **88** extends through the inside of collet **93** and terminates in a stud **94** which extends through insulator plate **95** which rests upon annular shoulder on the inside of collet **93**. Abutting plate **95** is a ring **96** similar to ring **51** described above in connection with Figs. 3 and 7. The edge of the lower rounded section of ring **96** rests upon and is in electrical contact with upper electrode **97** plated on piezoelectric crystal **98**.

A spider **99**, similar to spider **58** described hereinabove, is connected to stud **94** and its flexible blades make electrical contact with electrode **97**. Another electrode **101** is plated on the lower side of crystal **98** and is contacted by an annular flange **102** on retaining ring **103** which is threaded on collet **93** and maintains crystal **98**, ring **96** and plate **95** in position. Flange **102** also may have a contour similar in shape to that of rings **46** and **51** whereby arcing is minimized. Electrode **101** is electrically grounded through flange **102**, ring **103**, collet **93** to outer conductor **91**.

The crystal end of the probe may be inserted into breakers or tanks containing various materials or organisms that are to be subjected to ultrasonic vibrations which would be inconvenient in reaction chamber **45**. Also the crystal end of the probe may be applied to various parts of animal and human bodies where such treatment is indicated.

Fig. 12 shows how the reaction chamber **45** may be adapted to treat materials in a continuous flow procedure. An overflow outlet **105** is provided to which a suitable pipe or tube can be connected while an inflow tube **106** is provided for introducing the material to be treated, the arrows in the drawing indicating the direction of flow.

The temperature of the reaction chamber within tube **45** may be controlled, as shown in Fig. 13, by means of a jacket **107** surrounding tube **45** and through which heat exchange liquid may be circulated. The flow may be introduced to jacket **107** through inlet tube **108** and emerges through outlet tube **109**.

In Fig. 14 there is shown a means of protecting the upper electrode **53** on crystal **54** by a film **112** of suitable inert material of plastic or the like applied over said electrode and which would be impervious to corrosive or other deleterious materials that might be present in some substances that may be treated in the reaction chamber.

The nature of the material in the reaction vessel **45** may be deleterious to electrode **53** which often is made of electroplated or vapor deposited silver. To insure that electrode **53** does not corrode nor interact with the material to be treated, said electrode may be made of gold, chromium or other suitable conductive substance that would be inert relative to the particular contents of the reaction chamber.

It will be understood that modifications may be made in the design and arrangement of parts without departing from the spirit of the invention.

What is claimed is:

1. A crystal assembly comprising a piezoelectric crystal, a plated electrode bonded upon two opposite faces of said crystal, a separate ring member for each of said electrodes, said ring members being removably applied in contact with substantially the peripheral area only of said respective electrodes, the outer peripheral surfaces of said ring members curving outward from the edges of said electrodes and away from the mass of said crystal.

2. Means for preventing arcing between a piezoelectric crystal and the sharp edges of electrodes plated on opposite faces of said crystal comprising a ring member for each of said electrodes, said members, being adapted to being removably applied in contact with the peripheral edges of respective electrodes, the periphery of said members being curved to contact the electrodes so as to blend with said edges thereby to diminish the sharpness of said edges.

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