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2,488,290

PIEZOELECTRIC CRYSTAL HOLDER

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Fig. 1.

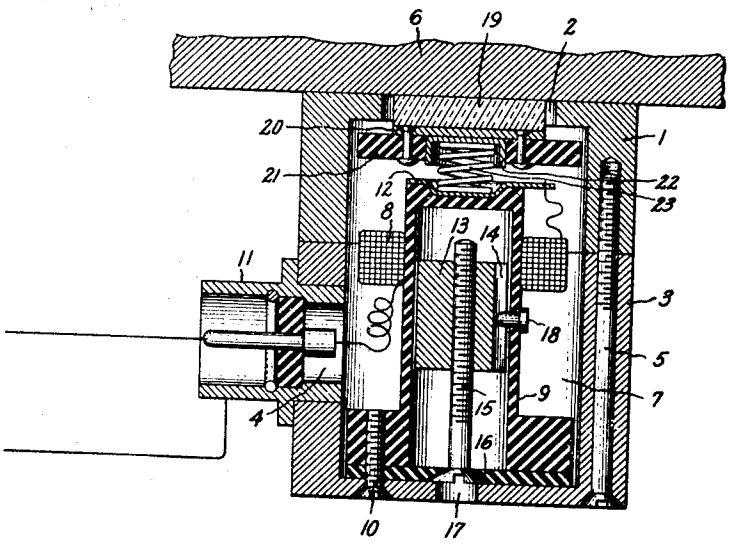



Fig. 2.

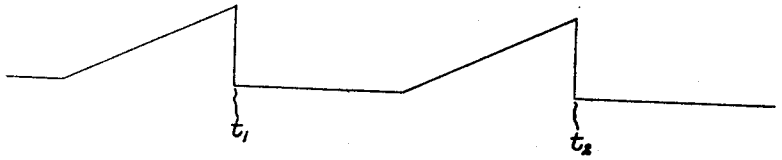
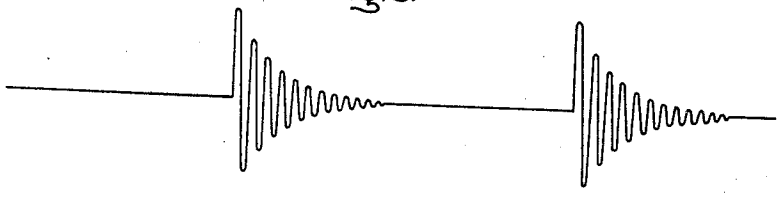



Fig. 3.



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# UNITED STATES PATENT OFFICE

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## PIEZOELECTRIC CRYSTAL HOLDER

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9 Claims. (Cl. 171—327)

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My invention relates to piezoelectric crystal holders, and more particularly to a holder for a piezoelectric crystal for use as a transmitter or receiver in ultrasonic inspection apparatus, and which includes a tuneable impedance within such holder.

Non-destructive methods of inspecting materials, such as iron or other metals, by transmitting mechanical vibrations of ultrasonic frequency into the material have been developed and are known in the art. These methods may utilize continuously produced mechanical vibrations or a series of short-duration mechanical vibration wave trains or pulses. Constant or variable frequencies have been employed.

Mechanical vibrations may be set up in the material to be analyzed by placing a piezoelectric crystal against the material, and cut to vibrate in the thickness mode and energizing the crystal from an appropriate electrical source of oscillations. In order to make the crystal available at the desired locations upon the material to be analyzed, it is usually necessary to utilize a transmission line, preferably a coaxial or concentric conductor cable, of appreciable length between the crystal and the energizing source. As a result, energy transfer sufficient to cause mechanical vibration of the crystal is necessary over such a transmission line and losses occur in it.

As used in ultrasonic testing apparatus, the piezoelectric crystal is subject to damping of its mechanical vibrations by coupling with the crystal holder and the inspected material, and the electrical impedance of the crystal is substantially a capacitance. As is known, a capacitance in an alternating current circuit stores energy received from the A.-C. source during a half cycle of the A.-C. source and returns this energy to the source during the next half cycle. It is also known that an inductance acts similarly, except that its energy storage occurs during the time a capacitance is returning energy to the system. Therefore, if an inductance and a capacitance are connected together in a circuit and are made equal as to energy storage capacity, energy will be transferred from one to the other. In other words, the capacitive reactance of the crystal requires a current which leads the voltage across the crystal by 90°. These 90° out-of-phase, or reactive, components of current and voltage transmit no real or useful power, but do add to the losses in the cable connecting the crystal holder to the energizing source. An inductive reactance, however, requires a current which lags

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the voltage across the inductance by 90°. Therefore, if inductive and capacitive reactances of equal magnitude are combined, forming a resonant circuit, the inductive and capacitive components of reactive power, being equal and 180° out of phase, cancel, thus reducing losses in the cable.

Furthermore, it will be found that the characteristic impedance of the transmission line is more nearly matched by the impedance of an inductance and piezoelectric crystal in series resonance than by an impedance consisting of a piezoelectric crystal only. Thus, the addition of an inductance coil in series resonance with a piezoelectric crystal will decrease materially the degree of mismatch between the characteristic impedance of the line and the terminal impedance including the crystal, and render the input impedance of the transmission line so terminated more fully independent of the transmission line length, and also eliminates electric wave reflections at the end of the line, according to known transmission line theory. Thus, more efficient transmission of energy to the terminating impedance is possible, and little, if any, change in the output impedance of the energizing source supplying such a transmission line need be made to obtain proper balance between such output impedance and the output impedance of the transmission line terminated by such load impedance even when transmission lines of various lengths are substituted for each other.

It is an object of my invention to provide a piezoelectric crystal holder which accommodates a tunable resonant circuit including the piezoelectric crystal, thereby allowing increased efficiency in the transmission line between the piezoelectric crystal and its energizing source.

Another object of my invention is to provide a piezoelectric crystal holder of compact size containing an adjustable tuning coil and a crystal in a structure of such design that the crystal is shielded from extraneous mechanical and electrical influences while allowing easy tuning adjustment of such coil.

The features of the invention which are believed to be novel and patentable will be pointed out in the claims appended hereto.

For a better understanding of the invention, reference is made in the following description to the accompanying drawing in which Fig. 1 discloses a piezoelectric crystal holder containing an adjustable tuning coil which is constructed in accordance with the principles of my invention; Fig. 2 represents a voltage variation which may

be employed in a manner to be described, and Fig. 3 is a second voltage variation shown for purposes to be described.

Referring to Fig. 1, a hollow cylindrical casing or cup 1, with an opening 2 in one end thereof, is fitted with a cylindrical cover 3 in which an opening 4 is provided for purposes to be described. The cover 3 may be held in place on casing 1 by any convenient means such as a screw 5. The end of casing 1 possessing the opening 2 presents a flat surface which may be made to engage with a material 6 to be analyzed. Casing 1 and 3 combine to form a cylindrical chamber 7 whose diameter exceeds that of opening 2 by a desired amount.

A tuning coil 8 wound about a hollow cylindrical T-shaped member 9, preferably constructed of a dielectric material, is held in fixed position within chamber 7 by detachably affixing member 9 to cover 3 as by a screw 10. One end of coil 8 is attached to the center wire of a concentric-type connector 11 which may be fitted, as shown, in opening 4 of cover 3. The remaining terminal of coil 8 is connected to a metal contact member 12 mounted upon the opposite end of member 9 to that which is held against cover 3 by screw 10.

A slug 13, preferably made of powdered iron or other small particles of magnetic material cemented or otherwise held together, of cylindrical form and having its center bore threaded is fitted with an axially extending slot 14 in one surface thereof. A brass or copper slug of similar form may be preferable if very high frequencies are to be employed. A screw 15 engages the threads of the center bore, and the head of screw 15 is held against the inner surface of cover 3 by a cylindrical disk 16 through which screw 15 extends. An opening 17 is provided in cover 3 for access to the head of screw 15. A stud 18, passing through the wall of member 9, is provided to engage in slot 14 of slug 13, thereby preventing rotation of slug 13 when screw 15 is turned as by a screwdriver inserted into opening 17. Thus, by turning screw 15 the position of the slug 13 with respect to coil 8 may be adjusted without dismantling the casing.

A piezoelectric crystal 19 is mounted in any conventional fashion on a metal electrical conducting plate 20 which is, in turn, mounted on a cylindrical disk 21 of dielectric material whose diameter exceeds that of opening 2. Cylindrical disk 21 slidably engages the inner walls of chamber 7, thereby guiding crystal 19 through opening 2 without allowing contact between crystal 19 and casing 1. Electrical contact with plate 20 is provided through a central opening in cylindrical disk 21 by means of a cup-shaped metal member 22. A spring 23 whose ends rest upon member 12 and within cup 22 respectively mechanically urges crystal 19 outwardly through opening 2 and also provides an electrical contact between metal member 12 and the crystal, thereby completing the electrical circuit from the center conductor of concentric connector 11, through the coil 8, and through crystal 19. Electrical contact of the exposed surface of crystal 19 and material 6 to be analyzed and the contact between material 6 and casing 1 completes the electrical circuit between the two electrical terminals of connector 11.

In the usual type of crystal holder containing no tuning coil, the total required voltage necessary to set the crystal into mechanical vibration must be made available across the input terminals of the holder. Also, this voltage must be of ultrasonic frequency in order to drive the crystal at the desired frequency. In a crystal holder employing the principles of my invention, the applied voltage may be much smaller. This is made possible by tuning the coil 8, which is done by properly positioning the slug 13 with respect to it such that at the desired oscillatory frequency the inductive reactance of coil 8 and the capacitive reactance of crystal 19 are made equal. When such condition is reached, a resonant circuit results to which losses only must be supplied. It is well known that in such a circuit the voltage across either reactor exceeds the voltage across the two reactors in series.

Tuning coil 8 and crystal 19 in series constitute a circuit containing inductance and capacitance in series, which circuit may be set into damped self-oscillation by a sudden application or sudden variation of voltage across its terminals by any low internal resistance source. The cable connecting the crystal holder to the energizing source provides the necessary low impedance for closing the oscillatory circuit, since the capacitance between cable conductors and also between parts of connector 11 provides a relatively low impedance at the frequency of oscillation. Thus, if the energizing source tends to impress a voltage such as is represented in Fig. 2 across the terminals at connector 11, the electrical circuit of the holder will be driven into self-oscillation of a damped characteristic at time $t_1$ and $t_2$ of Fig. 2. The frequency at which the circuit oscillates may be adjusted by varying the position of slug 13 with respect to coil 8. Thus, a voltage of the nature represented in Fig. 3 will appear across the crystal 19 when the circuit is energized by a voltage as represented in Fig. 2.

I have employed a circuit of the nature described with satisfactory results when tuned to essentially one megacycle frequency. Other frequencies can obviously be employed by readjusting the tuning coil or by substitution of a similar tuning coil containing a different number of turns. A source voltage of any other desired shape may also be utilized in place of that shown in Fig. 2, and the same conditions will apply if such source voltage contains sharply decreasing or increasing portions therein.

It is also possible to utilize a source voltage of the type represented in Fig. 3, or of any other shape including a constant magnitude oscillating source whereby resonant conditions will be continuously maintained in the circuit within the holder. In any case, it is apparent that the voltage across crystal 19, by which crystal 19 is set into vibration, will be greater than the source voltage applied to connector 11 because of the presence of tuning coil 8 in series with the crystal 19. This remains true whether the circuit within the holder is operating at its resonant frequency, or only reasonably close to resonance. The voltage increase is greater, however, when resonance occurs, which condition may be readily obtained by adjusting the position of slug 13. It is, therefore, apparent that my invention operates at a greater efficiency and requires a smaller total voltage input than do previously known types of crystal transmitters or receivers.

As will occur to those skilled in the art, various different arrangements and combinations of the principles described above may be employed without departing from the true spirit and scope of the invention and I, therefore, do not wish to

limit my invention to the particular arrangement described.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a base adapted to be placed upon a material to be analyzed, a piezoelectric crystal, crystal mounting means adapted for affixing one surface of said crystal thereon, means supported by said base and yieldably urging said mounting means toward such material on which said base may be placed for contact between the second surface of said crystal and such material, an inductively wound coil insulatedly mounted on said base, and means connecting said coil and said crystal in electrical series resonant relationship.

2. In combination, a base adapted to be placed upon a material to be analyzed, a piezoelectrical crystal, crystal mounting means adapted for affixing one surface of said crystal thereon, means supported by said base and yieldably urging said mounting means toward such material on which said base may be placed for contact between the second surface of said crystal and such material, an inductively wound coil insulatedly mounted on said base, means for varying the inductance of said coil, and means connecting said coil and said crystal in electrical series relationship.

3. In combination, a base adapted to be placed upon a material to be analyzed, a piezoelectric crystal, crystal mounting means adapted for affixing one surface of said crystal thereon, means supported by said base and yieldably urging said mounting means toward such material on which said base may be placed for contact between the second surface of said crystal and such material, an inductively wound coil insulatedly mounted on said base, means connecting said coil and said crystal in electrical series relationship, and means for shielding said coil and said crystal from stray electrical fields.

4. A piezoelectric crystal holder comprising a hollow casing having at least one opening therein, a piezoelectric crystal, mounting means for said crystal within said casing adapted to yieldably urge said crystal into the opening in said casing for exposing one surface of said crystal exteriorly, an inductance coil within said casing, and connecting means adapted to electrically connect said coil in series resonant relationship to said crystal.

5. A piezoelectric crystal holder comprising a hollow casing having at least one opening therein, a piezoelectric crystal, mounting means for said crystal within said casing adapted to yieldably urge said crystal into the opening in said casing for exposing one surface of said crystal exteriorly, an inductance coil within said casing, means for varying the inductance of said coil, and connecting means adapted to electrically connect said coil in series relationship to said crystal.



6. In combination, a hollow cylindrical casing having an opening in a flat surface thereof, a piezoelectric crystal, mounting means for said crystal for yieldably holding said crystal within the opening in said casing for exterior exposure of one surface of said crystal, an inductance coil mounted within said casing, and connecting means adapted to place said coil and said crystal in electrical series resonant relationship.

7. In combination, a hollow cylindrical casing having an opening in a flat surface thereof, a piezoelectric crystal, mounting means for said crystal for yieldably holding said crystal within the opening in said casing for exterior exposure of one surface of said crystal, an inductance coil mounted within said casing, means within said casing for varying the inductance of said coil, and connecting means adapted to place said coil and said crystal in electrical series relationship.

8. In combination, a hollow cylindrical casing having an opening in a flat surface thereof and constructed of metal possessing good electrical conductivity characteristics whereby shielding of elements mounted therein is accomplished, a piezoelectric crystal, mounting means for said crystal for yieldably holding said crystal within the opening in said casing for exterior exposure of one surface of said crystal, an inductance coil mounted within said casing, and connecting means adapted to place said coil and said crystal in electrical series resonant relationship.

9. In ultrasonic testing apparatus having a piezoelectric crystal and a crystal holder therefor connected by a cable to other parts of the apparatus, the crystal holder including means to hold one face of the piezoelectric crystal in contact with material to be tested, the improvement which comprises providing at the crystal holder a reactor connected to the piezoelectric crystal and therewith forming a resonant electric circuit, said resonant circuit being connected as the terminating impedance of the cable.

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