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MECHANICAL VIBRATING SYSTEM

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FIG. 1

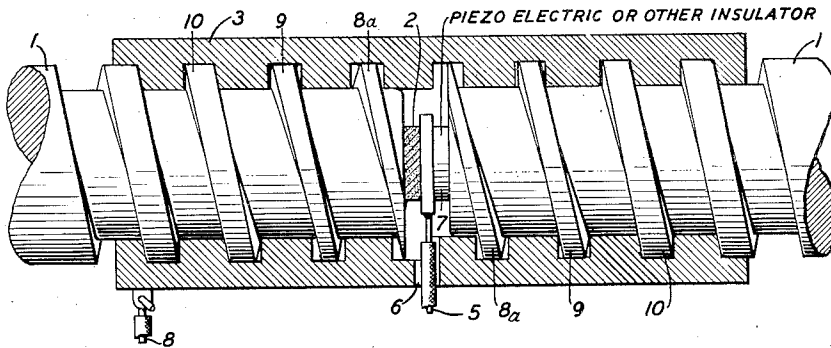


FIG. 2

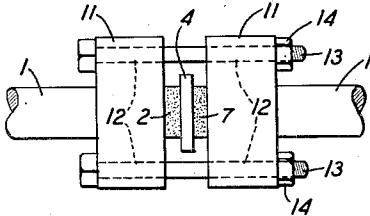


FIG. 3

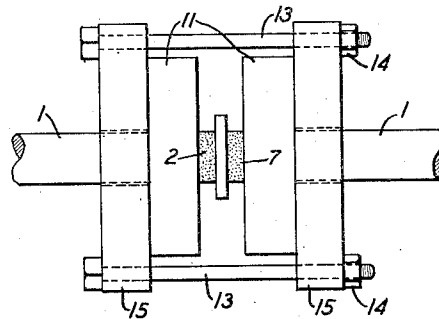


FIG. 4

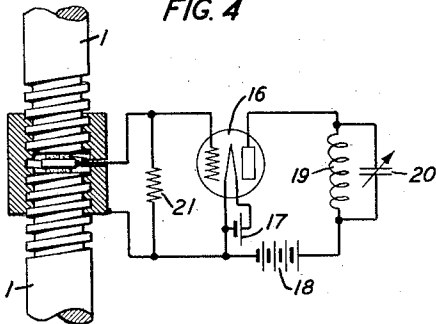
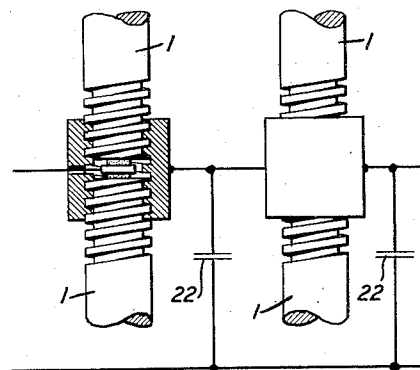


FIG. 5



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MECHANICAL VIBRATING SYSTEM

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10 Claims. (Cl. 171-327)

This invention relates to a mechanical vibrating system and particularly to means for efficiently driving an elastic mechanical vibratory element by a piezoelectric crystal element.

5 A piezoelectric crystal driven mechanical vibratory element is alternative to tuning forks, bars, or the like, as conventionally driven by electromagnetic or electrostatic means, in fact, has certain particular advantages thereover which
10 commend it for use in certain fields. However, the prior means of coupling the driving crystal element to the driven vibratory element, commonly involving the use of a cement-like material or a frictional engagement, have not been all
15 that might be desired as not being mechanically secure for a sufficiently long life, as being unadaptable to variation of coupling, and as tending to introduce anomalous frequency effects due to the use of masses of material not directly
20 concerned with the driving or vibratory functions.

It is therefore an object of the invention to provide a positive coupling between the piezoelectric driving element and the mechanical vibratory element, a coupling which will tend to be
25 mechanically secure through all exigencies of use, which is not attended by the use of extraneous material, and which is adaptable to variation so as to provide, not only a satisfactory form of, and desired closeness of, coupling between the
30 two significant elements, but also a coupling which itself has a frequency desirably outside the range of frequency of the mechanical vibratory element.

35 The vibration system of the invention comprises a pair of elastic mechanical vibratory elements or, as alternately considered, a divided elastic mechanical element, between which, or the portions of which, a piezoelectric crystal element is compressibly engaged by means of a nut
40 or turnbuckle threaded on the adjacent ends of the two mechanical vibratory elements, or by means of bolts passing through flanges or collars on the adjacent ends of the elements. Variation
45 in the closeness of coupling may be accomplished in the one case by narrowing the threads near the ends of the mechanical vibratory elements next adjacent to the crystal element as compared with the more remote threads, so that contact between the mechanical vibratory elements and the
50 nut or turnbuckle occurs only on the threads at a desired distance from the piezoelectric crystal; or, in the other case, by varying the dimensions, and thereby the stiffness, of the flanges or collars, and/or by varying the length, diameter and

number of the bolts engaging the flanges or collars.

In either form of the coupling employed, the single piezoelectric crystal element contemplated above may be replaced by two similar crystal
5 elements of the so-called "perpendicular cut" and faced oppositely so as to add their individual effects in phase.

Although ideally the ultimate frequency is that characteristic of the mechanical vibratory element alone, it is to be presumed that this frequency is somewhat affected by the mass of the nut or turnbuckle or other coupling means, so that the frequency is actually a function, com-
10 positely, of the mechanical vibratory element proper and the coupling means. Hence, it may be desirable to make the mass of the coupling means as small as possible and its material to simulate as nearly as possible that of the vibra-
15 tory element proper.

20 The nature and purpose of the invention will be more clearly understood from the following detailed description and by reference to the accompanying drawing, of which:

Fig. 1 illustrates one form of the invention, 25 with means for varying the closeness of coupling;

Figs. 2 and 3 show modified forms of the invention; and,

Figs. 4 and 5 are circuit diagrams illustrating uses and applications of a piezoelectric crystal
30 driven mechanical vibratory element utilizing the coupling means or methods of the invention.

In all of the figures of the drawing similar reference characters are used to designate similar parts.

35 Referring to Fig. 1, in which some details of the invention are shown somewhat out of scale for the sake of clearness, the numeral 1 designates a metal rod divided into halves and threaded on the adjacent ends, between which a plate or disc 2 of piezoelectric material is held under compression by means of a nut 3 engaging the threads of the two halves of the rod. Adjacent
40 to one face of the crystal element is a thin metal plate or disc 4 intended to serve as an electrode, to which is connected a lead 5 passing through an orifice 6 in the nut and insulated therefrom by suitable means. The electrode 4 is insulated from the rod by means of a plate or disc 7 of
45 some rigid insulating material such as glass, quartz or porcelain. The rod itself, being in contact with the other face of the crystal element, serves as a second electrode and to some convenient point thereon is electrically connected a 55

lead 8, which, with the lead 5, may be used to connect the device in an electrical circuit.

As most suitable for the object in view the piezoelectric plate (crystal element) 2 is preferably a quartz plate of the so-called "perpendicular cut", utilizing longitudinal vibrations in the thickness direction; that is to say, the plate is cut with its faces having such relation to the principal axes of the natural crystal that when an alternating voltage is applied to the electrodes there will be compressional vibrations of the plate perpendicular to its principal faces, which may be transmitted to the rod and impart to it a longitudinal vibration. This requires that the element be cut from the natural crystal so that its principal faces are perpendicular to certain sides or facets of the natural crystal.

The rod 1 may be of any metal of good elastic properties, as, for example, steel. If it is composed of a suitable alloy having a low temperature coefficient of expansion, this will be advantageous in maintaining a constant frequency and a rod of such material is therefore to be preferred.

The nut 3 is preferably of the same material as the rod and should be of such mass and dimensions that its natural frequency is much greater than that of the rod alone, so as not to complicate the function primarily in mind, that is, the driving of the rod at its own frequency by the crystal whose natural frequency is different.

The mechanism of operation of the device is as follows: With the nut 3 adjusted so that the crystal is under compression, an alternating voltage of high frequency applied to the exciting electrodes by means of the leads 5 and 8 will cause the crystal to expand and contract along its thickness direction in synchronism with the applied voltage, and these forced vibrations will be transmitted to the rod 1 by virtue of its elasticity and that of the coupling nut 3. When the frequency of the alternating voltage is of the right value, the rod and nut will be set into vigorous resonant vibration at the natural frequency of the combination, which is the desired result. Under this condition there is a counter electromotive force developed by the crystal on the two electrodes due to its alternate expansion and contraction, which may be made use of in electrical circuits in exactly the same manner as in the case of a vibrating crystal alone.

Since it is in general desirable to have such a degree of coupling between the crystal and the vibrating rod as to set up vibrations of the greatest possible amplitude, it is advantageous to be able to adjust this coupling. One method by which this may be accomplished is to narrow some of the threads on the ends of the rods adjacent to the crystal, such as 8a and 9 so that no pressure is exerted thereon by the nut when in compression adjustment. The pressure is then taken up by threads further apart, as by threads 10 and those beyond, so that a greater length of material of the nut exists between the areas of application of the pressure. Under this condition, for the same force exerted by the crystal in its expansion it will be able to expand further and hence a greater amplitude of vibration can be imparted to the rod. The shifting in this manner of the areas of pressure for the most desirable degree of coupling can best be determined by experiment. In this connection it is obvious, of course, that the thickness of the nut will also be a determining factor in the coupling.

An essential feature of the invention is that the piezoelectric crystal is at all times held under

compression between the two halves of the mechanical vibratory element. To accomplish this object satisfactorily various modifications of the form of coupling above described may be employed, one such modification being shown in Fig. 2. In this illustration the two halves of the rod 1, instead of being threaded as in Fig. 1, are provided with flanges 11 on the adjacent ends, integral with the material of the rod, and through holes 12 in these flanges bolts 13 of the same or similar material are passed and tightened by nuts 14 so that the piezoelectric plate 2 may be compressibly engaged as before.

Another modification of the form of coupling is illustrated in Fig. 3, wherein collars 15 of suitable material, preferably the same as the rod, are shown slipped over the rod in contact with flanges 11 such as are provided in Fig. 2, the two halves of the rod being drawn together by means of bolts 13 and nuts 14 engaging the collars, in the same manner as in the case of the flanges 11 in the preceding example.

In each form of the coupling illustrated, the elastic properties, mass and dimensions of the material comprising the coupling means, as already indicated with reference to Fig. 1, should be such that the vibrations of the piezoelectric plate are most effectively transmitted to the rod. To this end it is essential that the natural frequency of each component part of the coupling, or the natural frequency of the coupling as a whole, shall be greater than that of the rod. In the modifications shown in Figs. 2 and 3, the closeness of coupling will depend upon the length, diameter and number of the bolts 13, and the stiffness, and hence the dimensions, of the flanges 11, and, in the case of Fig. 3, upon the dimensions of the collars 15, and hence the coupling may be adjusted for best results by altering one or more of these factors. In so doing, however, due regard must be had for the effect of the mass of the coupling means upon the natural frequency of the composite ensemble.

As a further modification of the invention, the insulating plate 7 may be replaced by a second piezoelectric crystal cut in the perpendicular direction like the plate 2 but faced in the opposite direction. When the piezoelectric elements are so faced oppositely, they tend to contract or expand in like phase and therefore the amplitude of crystal movement may be doubled. In this arrangement the metal plate 4 becomes one exciting electrode for both piezoelectric plates, the other effective electrode being the rod itself.

As an illustration of how a crystal driven mechanical resonator coupled in the manner of this invention may be used in place of an ordinary piezoelectric crystal alone, reference may be had to Fig. 4, which shows a simple and well-known type of vacuum tube oscillator circuit. In this figure, 1 is the crystal driven rod, 16 is a three-element vacuum tube with filament battery 17 and plate battery 18, 19 is an inductance in the plate circuit paralleled by a condenser 20, and 21 is a high resistance connecting the grid directly with the filament. The coupling between the plate and grid circuits is the capacity existing between the plate and grid electrodes of the vacuum tube, and the condenser 20 serves to tune the plate circuit to approximately the same frequency as the mechanical frequency of the crystal driven rod in order to facilitate the transfer of energy from the plate circuit to the grid circuit. The oscillation frequency is determined by the natural frequency of the rod.

As another illustration of its application, there is shown in Fig. 5 a crystal driven resonator used as a circuit element in an electrical filter. In this illustration the filter is a recurrent ladder type structure, of which two sections are shown, each section containing a crystal driven resonator 1 in series with the line and a suitable condenser 22 in shunt with the line. It is well known that properly designed filters of this character are well suited to pass a narrow band of frequencies with very sharp cut-offs.

What is claimed is:

1. A piezoelectric crystal driven vibrating system comprising a piezoelectric crystal driving element, an elastic non-piezoelectric mechanical vibratory driven element, positive variable coupling means between said elements, and means for utilizing the characteristic elastic vibratory frequency of said driven element.
2. A piezoelectric crystal driven vibrating system comprising in combination, a piezoelectric crystal driving element, a divided non-piezoelectric mechanical vibratory driven element, means compressively engaging said crystal element between the portions of said divided mechanical vibratory element, and means for utilizing the characteristic elastic vibrational frequency of said driven element.
3. A mechanical vibratory system comprising a divided mechanical vibratory element of generally rod-like form and including constraining means at adjacent ends of the component portions thereof, a piezoelectric crystal device between said ends, and a coupling means coacting with said constraining means for compressively engaging said crystal element between the portions of said mechanical vibratory element.
4. A mechanical vibratory system like that of claim 3 in which the coupling means is so dimensioned that its natural frequency of vibration is substantially greater than that of the mechanical vibratory element.
5. A mechanical vibratory system like that specified in claim 3 in which the adjacent ends of the vibratory element portions are screw threaded to constitute the constraining means and the coupling means is a nut or turnbuckle element threadedly engaged with the ends of the vibratory element and turned up so as to compressively engage the crystal device therebetween.
6. A mechanical vibratory system like that specified in claim 3 in which the adjacent ends of

the vibratory element portions are flanged to constitute the constraining means and the coupling means comprises clamping means engaging the relatively remote flange surfaces with such constraint as to compressively engage the crystal device between said vibratory element portions.

7. A mechanical vibratory system like that specified in claim 3 in which the adjacent ends of the vibratory element portions are flanged to constitute the constraining means and the coupling means comprises one or more sets of bolts and nuts coacting, through orifices in said flanges, with the relatively remote surfaces of the flanges to compressively engage the crystal device between the vibratory element portions.

8. A mechanical vibratory system like that specified in claim 3 in which the adjacent ends of the vibratory element portions are flanged to constitute the constraining means and the coupling means comprises a pair of collars each individual to a flange and assembled on a vibratory element portion to engage the flange surface most remote from the piezoelectric crystal device together with clamping means coacting with said collars so as to compressively engage the crystal element between the vibratory element portions.

9. A mechanical vibratory system like that specified in claim 3 in which the adjacent ends of the vibratory element portions are screw threaded to constitute the constraining means and the coupling means is a nut or turnbuckle element threadedly engaged with the ends of the vibratory element and turned up so as to compressively engage the crystal device therebetween, a certain consecutive number of threads on the vibratory element portions next adjacent to the crystal device being relatively deformed so that no initial pressure is exerted thereon by the nut when in compression adjustment, whereby a predetermined length and mass of the nut material may be caused to exist between the areas of application of the pressure to correspondingly permit an optimum degree of expansion of the crystal device and hence a maximum amplitude of vibration can be imparted thereby to the mechanical vibratory element.

10. A mechanical vibratory system like that specified in claim 3 in which the piezoelectric crystal device comprises a pair of piezoelectric crystal elements with an electrode element therebetween.

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