

Sept. 3, 1946.

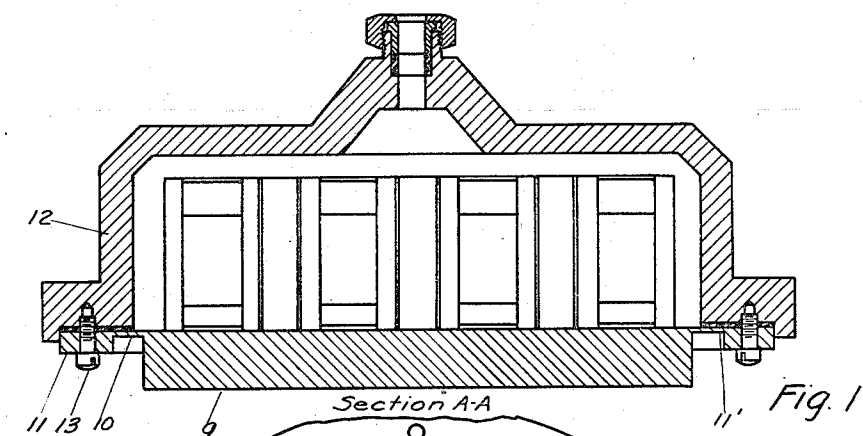
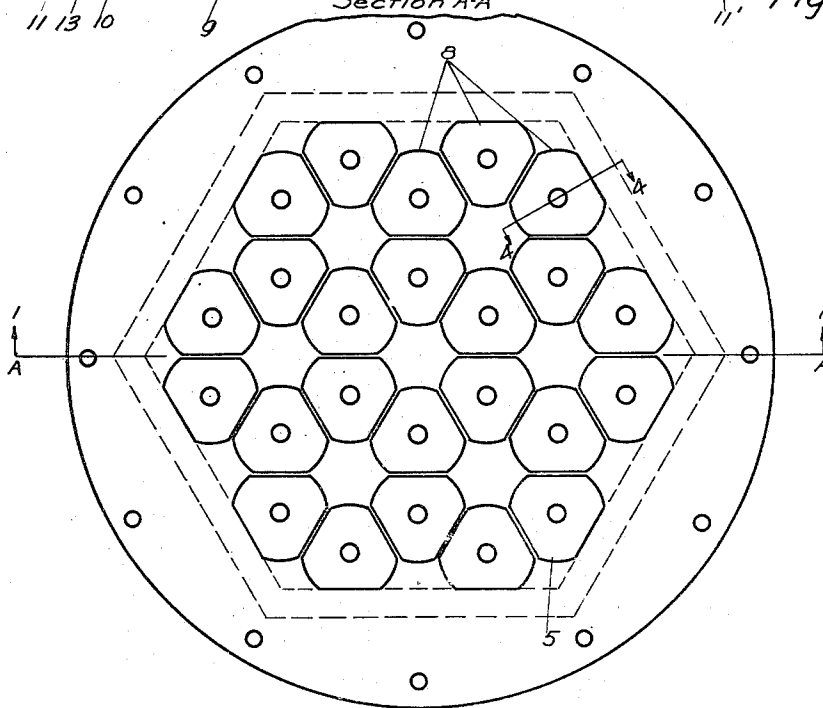
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2,406,792

PIEZOELECTRIC OSCILLATOR

Filed July 8, 1940

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

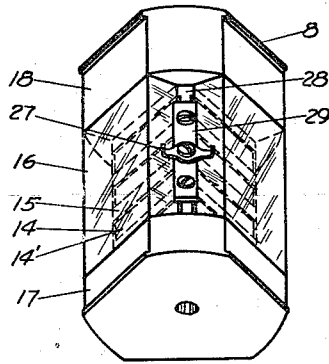


Fig. 3

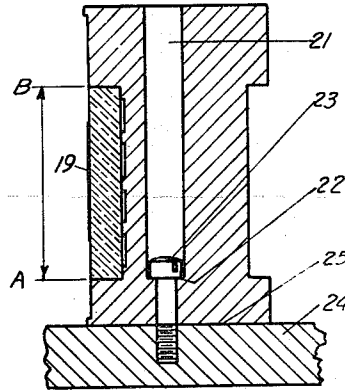


Fig. 4

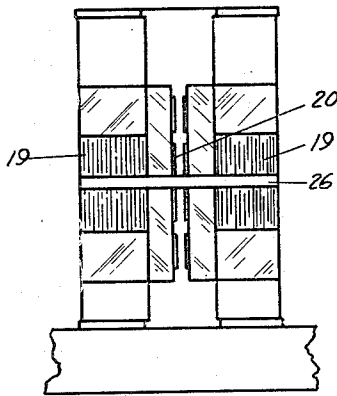


Fig. 5

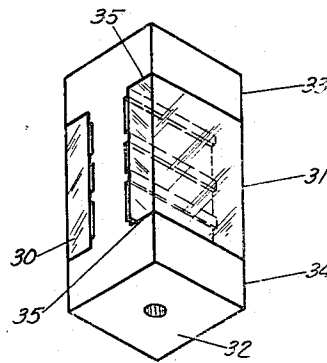


Fig. 6

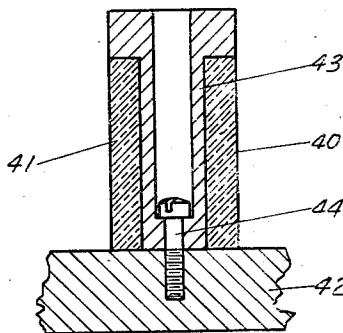


Fig. 7

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PIEZOELECTRIC OSCILLATOR

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Application July 8, 1940, Serial No. 344,363

18 Claims. (Cl. 177—386)

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The present invention relates to a tuned compressional wave vibrator in which the interchange of energy between mechanical and electrical oscillations is obtained through a piezoelectric crystal of the Rochelle salt or other similar type.

The principles of the present invention may be applied either to a unit of a small radiating surface, in which case the vibrator tends to be non-directional or to a vibrator which has large linear dimensions in comparison to the wave length to be transmitted in the propagating medium which may be air or water, but preferably water, to which the present invention is readily adapted.

In the present invention the piezoelectric oscillator is so arranged that it is vibrated or vibrates longitudinally in response to the application of oscillating or varying electrical potential across opposite faces of the crystal perpendicularly to the longitudinal vibrations. The crystal as a longitudinal vibrator is made to vibrate by compressional wave forces exerted at the crystal ends which act to vary the crystal length. Further, in order to eliminate spurious modes of vibrations it is desirable that the frequency of the lowest longitudinal mode of the crystal be higher than the operating frequency of the oscillatory structure in which it is mounted.

In the present invention the crystals may be arranged in triangular, rectangular, hexangular or other group patterns and these units, each comprising a single longitudinal vibratory structure, may be nested together on a plate which is designed so that the mass of the plate associated with each structure produces the desired sharpness of resonance. As the groups are distributed over the whole surface of the plate, the radiating face of the plate is vibrated in unison over its whole surface even though the plate is not inherently stiff enough itself to act as a piston.

The merits and advantages of the present invention will be more fully learned and understood from the description in this specification of an embodiment of the same described in connection with the drawings in which Fig. 1 shows a sectional elevation through the center of the device taken on the line 1—1 of Fig. 2; Fig. 2 shows a plan view as seen from the top of Fig. 1 with the back casing removed; Fig. 3 shows a perspective view of one of the units of Figs. 1 and 2; Fig. 4 shows a detailed section taken on the line 4—4 of Fig. 2; Fig. 5 shows an elevation of a single unit as viewed in the direction of the arrow 5 of Fig. 2; Fig. 6 shows a perspective view corresponding to Fig. 3 of a rectangular unit; and Fig. 7 shows in section a further modification.

In Figs. 1 and 2 there is a plurality of units 8, 8, 8, etc., mounted in hexagonal fashion on a heavy plate 9 the opposite side of which may be in contact with water and serve as the radiating surface providing thereby a proper seal so

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that the vibrating elements operate in air. The plate 9 is supported through a thin flange 10 and a heavy periphery ring 11 to the casing 12 by means of a series of bolts 13 spaced around the flange. A gasket 11' between the flange 11 and casing makes the casing watertight. The units 8 are nested together in a hexagonal pattern in such a way as to substantially cover the plate 9 which itself is hexagonal in shape. For other forms of plates different nestings and arrangements of units may be employed and the rectangular unit shown in Fig. 6, for instance, will cover a rectangular plate surface more completely than the unit of Fig. 3. The unit 8, which may be made from a solid piece of material, has a triangular center section 14 with flat faces 14' which may have a plurality of outwardly projecting ribs 15 which keep the piezoelectric crystal 16 from resting against the wall surface 14' and thereby reducing frictional forces between the crystal and this surface. At the ends of the triangular section 14 there are provided mass sections 17 and 18, each having outwardly extending flanges. The elements 17 and 18 are preferably of substantially the same shape as the triangular section 14. This manner of construction of the unit 8 permits the mounting of three piezoelectric crystals one against each face 14' of the triangular section. These crystals 16 are cemented against the ribs 15 and to the surfaces of the end bearing projecting flanges in such a way that they are firmly fixed to the metallic structure so that no play can exist between the flange and the ends of the crystal. These crystals are so cut that changes in length brought about by varying pressures applied lengthwise of the crystals at their upper and lower ends will set up electrical variations in potential between the electrodes 19 and 20 mounted on opposite crystal faces.

Each unit is supported to the plate in the manner indicated in Fig. 4. A hole 21 is bored through the center of the unit and at the lower end is provided with a shoulder 22 against which the head of the screw 23 bears as it is screwed into the plate 24. It is also essential to cement the unit to the plate between the contacting surfaces at 25 as it is essential to provide a continuous acoustic path to make the plate 24 a part of the longitudinal vibratory acoustic structure.

Other methods of coupling the unit 8 to the plate may be employed as, for instance, a fluid coupling of some plastic or viscous material. However, the method indicated here has proved to be preferable in this construction.

The crystals mounted in each unit may be connected in parallel or series parallel by proper insulation of the crystal electrodes. In this case the electrodes 19 on the outside surfaces of the unit may be all connected together by a band 26 which is connected to a terminal connector 27

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mounted by means of the insulating block 29 on the flat surface 23 at the junction of the faces of the triangular section. The metal of the unit itself forms the connection for the electrodes on the inner faces of the crystals. The electrodes may also be extended to form leads.

In the unit shown in Fig. 6 the structure is quite similar to that in Fig. 3 with the exception that the unit provides only two crystals 30 and 31, one on each of two opposite faces of the unit. The unit 32 of Fig. 6 is provided with end masses 33 and 34 which have projecting flanges 35 hanging over and bearing upon the ends of the crystals. In the operation of the device the metallic structure of the unit 8 with its base portion as, for instance, the section indicated by 24 in Fig. 4, forms a longitudinal vibratory structure at a definite resonant frequency.

The nodal point may either be between the lines A and B, referring to Fig. 4, or the nodal point may be outside of this section although where the units are attached to a large diaphragm or plate in order to prevent transverse vibrations in the plate, it is for the most part desirable to have the nodal point outside or practically outside of the large plate.

In order to reduce spurious vibration modes at high frequencies the crystal 16 is cemented at its ends to the metallic flanges and the natural crystal frequency is chosen to have a longitudinal resonance well above that of the resonance of the metallic vibratory structure. Since, however, the crystal itself is firmly united with the metallic element to form a single unitary structure, the unit when assembled has only a single resonant point which is close to the resonance of the metallic system.

In the operation of the oscillator when the plate 9 is vibrated at the proper resonant frequency for the system, longitudinal vibration is set up in the unit 8, compressing and expanding the crystals 16 by action at their ends whereby the crystals 16 expand and follow the motion of the surfaces A and B. The end surfaces of the crystal will always keep in contact with the surfaces of the metal. When the metallic unit is vibrated, electrical potentials are set up across the electrodes 19 and 20; and conversely when electrical potentials are set up across the electrodes as when the device is used for transmitting compressional waves, the ends of the crystals exert pressure against the metallic surfaces A and B and produce longitudinal vibrations of the unit 8 in the plate 9.

In Fig. 7 a unit is shown in which the lower bearing surface for the crystals 40 and 41 is furnished by the plate 42 of the radiating member against which the crystals are cemented. The mechanical unit 43, which with the plate 42 is designed to form a resonant structure at the desired frequency, is held to the plate in the same way as explained above by means of the screw 44 which is screwed into the plate.

Having now described my invention, I claim:

1. A piezoelectric oscillator adapted to be used for transmitting and receiving compressional waves comprising a resonant longitudinally vibratory element having a recess with the shoulders of the recess at opposite sides of a node in the longitudinal system, a piezoelectric crystal having its ends cemented to said shoulders, said crystal having its mechanical axis parallel to the plane of longitudinal vibration and its electric axis transverse thereto.

2. A piezoelectric oscillator adapted to be used

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for transmitting and receiving compressional waves comprising a resonant longitudinally vibratory element having a recess with the shoulders of the recess at opposite sides of a node in the longitudinal system, a piezoelectric crystal having its ends cemented to said shoulders, said crystal having its mechanical axis parallel to the plane of longitudinal vibration and its electric axis transverse thereto, said crystal having a natural free resonance above that of the longitudinal vibratory unit.

3. A piezoelectric oscillator adapted to be used for transmitting and receiving compressional waves comprising a resonant longitudinally vibratory member formed with two end masses substantially greater than the portions of the member between the ends, a piezoelectric crystal mounted upon said member with its ends bearing upon said masses, the composite longitudinally vibratory structure so formed having a node between said end masses and having a resonant frequency substantially lower than that of the free resonant frequency of the piezoelectric crystal by itself.

4. A piezoelectric oscillator adapted to be used for transmitting and receiving compressional waves comprising a resonant longitudinally vibratable metallic structure having a central element with elements formed at each end providing heavier masses than the central element, said metallic structure having a node in said central element at the resonant frequency, said end masses forming parallel bearing surfaces, a piezoelectric crystal mounted between said bearing surfaces, said crystal being adapted to produce electrical variations between electrodes positioned in a plane substantially normal to the planes of said bearing surfaces.

5. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a plurality of piezoelectric crystals, a longitudinal structure having a substantially rectangular sectional shape with a plurality of mounting surfaces forming the faces of said rectangle, said unit having flanges extending at each end of the crystal, said piezoelectric crystals each mounted on one of said faces, said crystals having their ends and side cemented respectively to the said flange surfaces and faces whereby longitudinal vibration of said structure will produce corresponding vibrations in said crystals.

6. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a longitudinally vibrating resonant metallic system having a central longitudinal member connected to end masses providing opposing surfaces substantially normal to the longitudinal direction and a piezoelectric crystal mounted securely against said opposing surfaces.

7. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic system having a central longitudinal member connected by end masses providing opposing surfaces substantially normal to the longitudinal direction, a plurality of piezoelectric crystals mounted securely against said opposing surfaces and having their compressional axes substantially parallel to the longitudinal axis of the metallic vibratory system.

8. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic element symmetrically constructed with respect to the central longitudinal axis, said element having end

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masses providing flange surfaces opposite one another extending around said metallic element, and a plurality of piezoelectric crystals mounted with their compressional axes substantially parallel to said longitudinal axis between said opposite surfaces about said element.

9. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic element, said element having end masses providing flange surfaces opposite one another extending around said metallic element, and a plurality of piezoelectric crystals mounted between said opposite surfaces around said element with their compressional axes substantially parallel to the longitudinal axis of said element.

10. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic element, said element having end masses providing flange surfaces opposite one another extending around said metallic element, and a plurality of piezoelectric crystals mounted between said opposite surfaces around said element with their compressional axes substantially parallel to the longitudinal axis of said element, said longitudinal vibratory structure providing mounting supports against which the piezoelectric crystals rest.

11. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic element, said structure having end masses providing flange surfaces opposite one another extending around said metallic element, and a plurality of piezoelectric crystals mounted with their compressional axes substantially parallel to the longitudinal axis of said element and between said opposite surfaces around said element, the portion of said element between said end masses providing surfaces parallel to the longitudinal axis of the element, said surfaces having a plurality of projecting ribs against which said piezoelectric crystals rest.

12. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic element, said structure having end masses providing flange surfaces opposite one another extending around said metallic structure, and a plurality of piezoelectric crystals mounted with their compressional axes substantially parallel to the longitudinal axes between said opposite surfaces about said structure, said structure being triangular in shape and providing three surfaces extending parallel to the longitudinal axis, said surfaces having projecting ribs against which said crystals are mounted.

13. A piezoelectric compressional wave oscillator comprising a plate having a thin supporting web at the periphery thereof, a plurality of oscillator units each comprising a resonant longitudinally vibrating metallic element having end masses extending normally from the central portion of said vibratory element and providing opposed surfaces about the central portion of the vibratory element, a plurality of piezoelectric crystals cemented securely against said opposing surfaces and means acting through the axis of said longitudinal vibratory element securely holding said element to said plate, said plate and said oscillator unit combining to form each a resonant longitudinal vibratable structure with a node between the radiating surface and rear surface of the oscillator unit.

14. A piezoelectric compressional wave oscil-

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lator comprising a plate having a thin supporting web at the periphery thereof, a plurality of vibrator units each comprising a resonant longitudinally vibrating metallic element having end masses extending normally from the central portion of said vibratory element and providing opposed surfaces about the central portion of the vibratory element, a plurality of piezoelectric crystals mounted securely against said opposing surfaces, said vibrator unit having a bore extending through the center of said unit along the longitudinal axis, means acting in said bore to clamp the unit to said plate and means cementing together the clamping surfaces between the plate and said vibrator unit, said plate and said vibrator unit combining to form each a resonant longitudinally vibratable structure with the node between the radiating surface and the rear surface of the vibrator unit.

15. A piezoelectric compressional wave oscillator comprising a plate having a thin supporting web at the periphery thereof, a plurality of oscillator units nested together over substantially the whole plate surface, means clamping said oscillator units directly to said plate and each said unit forming with the section of plate adjoining the end a resonant longitudinally vibratory structure vibrating normal to the surface of the plate, each of said vibratory units providing end masses, said masses having bearing surfaces for mounting a plurality of piezoelectric crystals for compressional vibration with the mechanical axes parallel to said longitudinal axes.

16. An underwater compressional wave oscillator comprising a watertight casing having one side formed as a plate the outer face of which is adapted to act as a radiating surface, a plurality of vibrating elements mounted on the inner surface of said plate in close proximity to each other and each comprising a polyhedral structure having a longitudinal axis perpendicular to said plate and forming with a portion of said plate a resonant longitudinal vibrator, said polyhedral structure having a recess in one or more faces thereof and piezoelectric crystals mounted within said recesses with their ends cemented to the shoulders of said recesses and with their mechanical axes parallel to the longitudinal axis of the structure.

17. A piezoelectric oscillator adapted to be used for transmission and reception comprising waves including a vibrator comprising a resonant longitudinally vibratable element having recesses forming mass portions at each end of said element and Rochelle salt piezoelectric crystals mounted within said recesses and having their ends abutting and acoustically joined to the shoulders of said recesses with the mechanical axes of the crystals parallel to the longitudinal direction of said element whereby the crystals and said element form a unitary longitudinal vibrator having a natural fundamental resonant frequency with a node between the ends of the vibrator.

18. In a piezoelectric compressional wave oscillator, an oscillator unit comprising a resonant longitudinally vibrating metallic element having recesses in a plurality of its sides, a plurality of piezoelectric crystals mounted between and securely against the shoulders of said recesses and having their compressional axes substantially parallel to the longitudinal axis of the metallic vibratory element.

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