

April 24, 1945.

H. C. HAYES
SUPERSONIC APPARATUS
Filed Sept. 10, 1931

2,374,637

2 Sheets-Sheet 1

FIG. 1

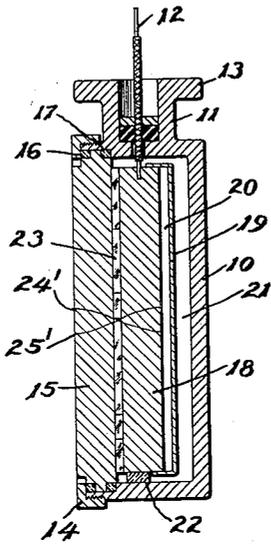
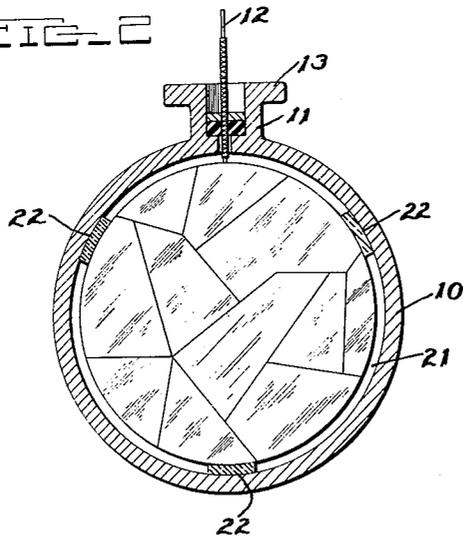


FIG. 2



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FIG. 4

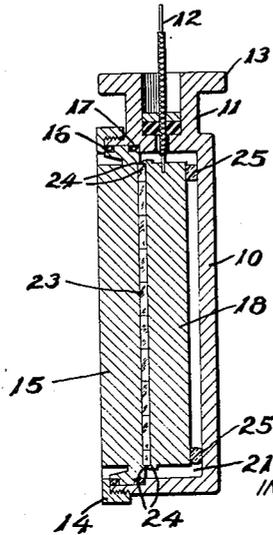


FIG. 4A

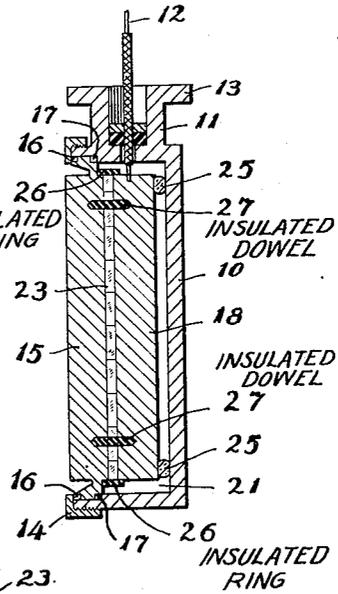
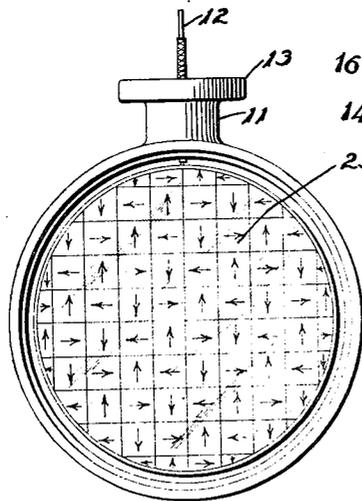


FIG. 3



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SUPERSONIC APPARATUS

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Application September 10, 1931, Serial No. 562,183

15 Claims. (Cl. 177-386)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to improvements in supersonic apparatus and particularly to a construction of sound transmitters and receivers which results in greater efficiency and reliability than has been had in apparatus heretofore available.

The objects of my invention are, first, to reduce internal losses resulting from the tangential or shearing forces along the surface of the plates, which forces are set up by the change in dimension of the crystals along the y -axis, caused by the change in field along the x -axis;

Second, to eliminate the loss due to friction between the inner plate and the insulating wedges;

Third, to eliminate the spun metal cap and to provide a steady pressure against the back of the plate to assure its positioning against the crystals;

Fourth, to provide a molecular contact between the crystals and the plates that is not destroyed by the jars incident to service or an arcing between the plates.

With the above and other objects in view, the invention consists in the construction, combination and arrangement of parts as will be hereinafter more fully described.

Reference is to be had to the accompanying drawings forming a part of this specification in which like reference characters indicate corresponding parts throughout the several views and in which:

Figure 1 is a section of a sound transmitter and receiver;

Figure 2 is a section through Figure 1;

Figure 3 is a side elevation of Figure 4 with the top plate removed;

Figure 4 is a section of my improved sound transmitter and receiver;

Figure 4A is a sectional view through the modification of the improved sound transmitter and receiver illustrated in Figure 4.

In Figure 1, reference number 10 is a cup-shaped casting provided with an outlet neck 11 through which an insulated lead 12 may enter through a water-tight stuffing-box and which carries a flange 13 by which the casing can be secured to any similar member, for instance, a periscope tube carrying at its end a similar flange. The rim of the cup is threaded to carry a threaded flange 14 designed to compress the disk-shaped member 15 between gaskets 16 and 17 to maintain water-tight integrity within the cup. Members 15 and 18, except for the flange on 15, are preferably identical as to thickness and material. They are metal disks with planes

parallel and with circular faces. These plates are separated by a mosaic of piezo-electric crystals 23 ground to uniform thickness and the whole combination, plates with intervening crystal mosaic, is solidly stuck together by means of a suitable cement or wax. The inner plate 18 carries a spun or pressed thin metal cap 19 which assures that the plate shall be backed by a layer of air 20 when the space 21 is filled with grease or a low-melting wax. Three or more insulating wedges 22, placed between plate 18 and case 10 help to support plate 18 so that the wax or cement which holds the combination 15, 18, 23 together need not bear the entire weight of plate 18. The electrical lead 12 connects with plate 18 which is insulated from all its surroundings. Plate 15 either directly or through water is grounded to case 10.

Figure 2 is a section through case 10 as far as plate 18 and in the central portion shows the nature of the quartz mosaic with plate 15 removed. Also, the circumferential location of the insulating wedges 22 is shown.

The principle of operation of a submarine sound transmitter and receiver, such as shown in Figures 1 and 2, is well known in the art and briefly is as follows: If the quartz crystals are cut so that the direction through them and perpendicular to the faces of the plates 15 and 18 is alike for each and along the x -axis of the crystal, then an alternating or fluctuating electric potential connected across the two plates 15 and 18 will expose the crystals to a varying electric field directed along their x -axis, and they will suffer changes in thickness in conformity with and in proportion to the variations of the electric field across them, or in other words, to the voltage variations across the two plates. If the voltage variations are made periodic and of the proper frequency the two plates with the intervening crystals will be thrown into oscillation as shown schematically by curves 24' and 25' of Figure 1. This is the natural or fundamental frequency of the plate-crystal combination and it is obvious that it could be oscillated at the odd harmonics of this frequency. The outside surface of plate 15, which is in contact with the water, generates the submarine sound.

Both laboratory and field tests have shown that the internal losses can be materially decreased and the generated sound energy correspondingly increased by a proper design and arrangement of the crystal mosaic. The explanation of this is as follows: The crystals must be cut as described, so that the electric axis is parallel

with the electric field between the plates, and this leaves the pressure or y -axis and the optical or z -axis parallel with the surfaces of the plates. It is well known that a change in field strength along the x -axis causes a change in length along both the x -axis and the y -axis, the change per unit length along both axes being practically the same. This results in a y -movement along the surface of the plates which is normally great compared with the x -movement because the y -dimension is much greater than the thin x -direction. Such motion creates tangential or shearing forces along the plate surfaces which tend to tear the quartz loose from the plates or at best to generate considerable heat along the surface planes which softens the wax to the point where it allows the plates to separate. It is obvious that the magnitude of such losses will increase with the dimensions of the crystals with respect to the y -axis and would become a maximum if the whole plate surface were covered by a single crystal. It follows that the magnitude of such internal losses will not be the same for two transmitters having plates of the same area, but provided with mosaics of different shaped and different sized crystals. The improvement which overcomes this difficulty is explained in connection with Figure 3 which shows a transmitter similar to Figure 2 with the exception that the mosaic is made of crystals cut to equal size and shape and having the angular relation between faces, edges and crystallographic axes in all crystals the same. In the construction shown the crystals are cut to square form with the y -direction corresponding to two opposite sides of the square and the z -direction to the other two sides. The x -direction is perpendicular to the plane of the paper. The best arrangement is had by placing the crystals so that the y -axes of any two adjacent crystals make an angle of ninety degrees with one another. Since the expansion along the z -axis is practically zero under the action of an electric field as compared with that along the y -axis, this arrangement gives the minimum shearing motion along the surface of the transmitter when considered for all directions along the surface. In fact, it gives a uniform shear in all directions along the surface. In Figure 3 the arrows represent the directions of the y -axes for the several crystals of the mosaic. Other forms than a square might be employed and would serve as well, but the cost of cutting crystals having the shape of a hexagon or the like would be more expensive.

The second improvement has to do with the elimination of the retaining wedges 22 which prove difficult to locate properly when assembling the apparatus and which at best fail to keep plate 18 pressed against the crystals. Since the combination 15, 23, 18 oscillates as a solid mass with a node in the midplane of the crystals, it is obvious that any supporting flanges or centering members should be placed as near as possible to this nodal plane to prevent damping losses. The wedges 22 introduce such losses because the cylindrical surface of the plate 18 has to rub back and forth along the surface of contact. Figure 4 shows an improvement on this construction. The plates 15 and 18 are machined and ground so that the face exposed to the quartz crystals carries a narrow edge 24 that projects about a millimeter out from the surface against which the crystals are mounted. As a result the plate 18 cannot shear across plate 15 because of the in-

setting of the crystal mosaic, and it is to be noted that in this way the retaining point or points which hold the oscillating system centered are located very near the nodal plane. It is obvious that the scheme of holding the plates centered axially by retaining them against each other rather than by anchoring each against the case, can be carried out in other ways, as illustrated in Figure 4A for instance, wherein an insulated dowel or dowels 27 pass from the plate 15 through the crystals 23 into the other plate 18. A neatly fitting band 26, made of insulating material, which will slide over the inner rim of both plates 15 and 18 with the crystal mosaic 23 intervening is also provided. While both the dowel and ring means have been shown in the single modification illustrated in Figure 4A, it is obvious that either one would be sufficient. The construction shown in Figure 4 and Figure 4A permits of accurate lining up of the oscillating system upon assembling and serves to keep them in alignment against jars and yielding of the wax or cement with time.

The construction shown in Figure 4 and Figure 4A has another improvement in that it eliminates the spun metal cap 19 and provides a steady pressure on the back of plate 18 so as to assure the positioning of this plate against the crystals by overcoming the separating action of its own weight and such jars and jolts as may be met in practice. This is accomplished by placing a rubber ring 25 between plate 18 and the back of case 10, the ring having dimensions such that it fits about the circumference of the plate and is compressed between the plate and case as shown. This construction reduces the cost of production and makes operation more sure by holding the inner parts rigidly in position. The space 21 can be filled with wax or grease as used in the construction of Figure 1.

Still another improvement has to do with the binding together of the two plates and the crystal mosaic. The wax or cement assembly described in connection with Figure 1 proves in practice to have three weaknesses. First, the plate and crystal combination separates under the action of slight sharp jars or of the heat generated when the device is driven under high electrical potentials so as to give intense sound signals. The amplitude of motion of the quartz crystals is so small that no sound energy is generated unless the whole combination is held in strict molecular contact and as a result the mere pressing together of the combination is not sufficient to make it function if the adhesive contact between wax and quartz or steel is broken; the wax must be remelted and allowed to harden before it will function. No wax or cement has been found that will not break at the surfaces of contact under the action of a short sharp blow and as a result the transmitters have not been considered thoroughly reliable for use on ship board. The second weakness lies in the fact that if the voltage across the plates happens to become sufficiently high to spark or arc across, the plates remain short circuited and useless because of the carbonization of the wax along the spark path. Such accidents often happen due to voltage surges when the circuit is broken and require that the whole combination be cleaned and reassembled. The third weakness lies in the fact that the natural frequency of the transmitter varies considerably with change in temperature, tending to become lower as the temperature is raised and vice versa.

The first two weaknesses have been entirely overcome and the third one greatly improved by

replacing the cement or wax used to bind the plates and quartz together with an oil of high insulating qualities and proper viscosity and capillary activity. Since the liquid wets the plate and quartz surfaces the condition of true molecular contact is always met and if the surfaces are ground and polished to an optical plane the thin oil film between metal and quartz is as rigid as regards the transmission of high frequency sound waves as is a wax or cement. Moreover, if a spark passes between plates and through the oil film it immediately heals over without leaving the plates short circuited. Thus, the first two weaknesses which have tended to make transmitters unreliable have been completely overcome. The change in frequency of the transmitter with varying temperature has been practically eliminated by a proper choice of oil. The thickness of the oil film separating the quartz and the metal is dependent upon the capillary force tending to pull the oil between the surfaces and also upon the pressure exerted by the rubber ring 25 which forces the surfaces together. The latter force is sensibly constant. The capillary force decreases as the temperature increases and as a result the thickness of the oil film varies somewhat inversely with the temperature, becoming thinner as the temperature rises and thicker as it falls. It is obvious that the natural frequency of the transmitter increases as the perpendicular distance between the outer face of 15 and the inner face of 13 decreases. It will thus be seen that the change in thickness of the oil films brought about by change in temperature is in the proper direction to compensate for the change in frequency incident to the change in temperature. This compensation can be practically effected by choosing an oil having the proper capillary activity and a rubber ring 25 which furnishes a proper amount of pressure between plates. A mixture of one-fourth linseed oil and three-fourths castor oil works well.

It will be understood that the above description and accompanying drawings comprehend only the general and preferred embodiment of my invention, and that various changes in construction, proportion and arrangement of parts may be made within the scope of the appended claims, and without sacrificing any of the advantages of my invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I am aware that prior to my invention supersonic transmitters and receivers have been constructed of metal plates with quartz crystals intervening. I therefore do not claim such a combination broadly; but I claim:

1. In a supersonic signaling device comprising an inner and an outer metallic plate with a mosaic of intervening quartz crystals, a method of reducing internal losses consisting of cutting the crystals to the same size and shape and so that in all crystals the angular relation between faces, edges and crystallographic axes is the same, and mounting said crystals between metallic plates so that the y -axis of each crystal is at right angles to the y -axis of any adjacent crystal.

2. In a supersonic signaling device comprising an inner and an outer metallic plate with a mosaic of intervening quartz crystals, a method of reducing internal losses consisting of cutting the crystals to the same size and shape and so that

in all crystals the angular relation between faces, edges and crystallographic axes is the same, and mounting said crystals between metallic plates so that the y -axis of a part of the crystals are in one direction and the y -axes of the remainder of the crystals are in a direction making an angle of substantially ninety degrees with the first direction, the crystals associated with each direction being intermixed.

3. In a supersonic signaling device comprising an inner and an outer metallic plate with a mosaic of intervening quartz crystals, a method of reducing internal losses consisting of cutting the crystals to square form with the y -direction corresponding to two opposite sides of the square and the z -direction to the other two sides, the x -direction being perpendicular to the plane of the square and mounting the crystals between the metallic plates so that the y -axes of any two adjacent crystals make an angle of ninety degrees with one another.

4. In a supersonic signaling device comprising an inner and an outer metallic plate with a mosaic of intervening piezo-electric crystals, a method of reducing the loss due to the shearing forces along the surfaces of the plates caused by the motion of the crystals, consisting of making the crystals as small as practicable, cutting the crystals to the same size and shape and so that in all crystals the angular relation between faces, edges and crystallographic axes is the same, and mounting the crystals between metallic plates so as to obtain a uniform shear in all directions along the surfaces of the plates.

5. In a supersonic signaling device comprising an inner and an outer metallic plate with a mosaic of intervening quartz crystals whose x -axes are perpendicular to and y -axes parallel with the surfaces of said plates, a method of reducing the loss due to the shearing forces along the surfaces of the plates caused by the motion of the crystals, consisting of making the crystals as small as practicable, cutting the crystals to the same size and shape and so that in all crystals the angular relation between faces, edges and crystallographic axes is the same, and mounting the crystals between the metallic plates so that the y -axes of any two adjacent crystals are at an angle to each other, whereby a uniform minimum shear in all directions along the surfaces of the plates is obtained.

6. In an ultra-audible sound signaling device comprising a containing case, an inner and an outer metallic plate with a mosaic of intervening piezo-electric crystals positioned within said case and secured thereto so that the back surface and peripheral sides of said inner plate form a void with said case, means for maintaining an air layer at the back of the inner plate when said void contains an insulating medium consisting of a rubber ring whose thickness is such that it is compressed between the back of the inner plate and case and whose diameter is such that it fits about the circumference of the inner plate.

7. In an ultra-audible sound signaling device the combination of an inner and outer plate with a mosaic of intervening piezo-electric crystals, an edge on each plate extending around the circumference and projecting out from the surface against which the crystals are mounted so as to embrace the crystals, a containing case for said plates and crystals so constructed as to leave a small space between the back of the inner plate and the back of the case, and a rub-

ber ring whose outer diameter is substantially the same as the diameter of the inner plate and which is concentrically placed on and compressed between the back of said inner plate and the case.

8. A supersonic signaling device comprising an outer and an inner metallic plate, a mosaic of piezo-electric crystals interposed between the plates, an oil for assuring adhesion between the contact surfaces of the plates and crystals, said oil being of proper viscosity and capillary activity whereby with change in temperature the thickness of the oil film between the plate and crystal surfaces compensates for the change in thickness of the plates and crystals maintaining a constant natural frequency in the plate-crystal combination.

9. In a supersonic signaling device comprising an outer and an inner metallic plate with a mosaic of intervening piezo-electric crystals, an oil for assuring adhesion between the contact surfaces of the plates and crystals, said oil having high insulating qualities and proper viscosity and capillary activity, and means for applying through an elastic substance a pressure to the back of the inner plate, whereby a break in said contact surfaces created by shock is automatically renewed, a rupture in the oil film caused by high potential across the plates is self healed and change in thickness of the plates and crystals due to change in temperature is compensated for.

10. A supersonic signaling device comprising an inner and an outer metallic plate, a mosaic of piezo-electric crystals interposed between the plates and liquid means for assuring adhesion between the contact surfaces of the plates and crystals, said liquid means containing substantially one-fourth linseed oil and three-fourths castor oil.

11. In a supersonic signaling device, a cupped shaped containing and supporting member, an inner metallic plate, an outer metallic plate, a mosaic of piezo-electric crystals interposed between said plates, means securing and hermetically sealing said outer plate to said cup member to maintain a water-tight integrity within said cup, means supporting said inner plate at substantially the nodal plane of the plate crystal combination so that said plate will be spaced from said cupped member and its vibrations undamped by surface contact therewith, an oil film of high insulating qualities between said plates and crystals for maintaining molecular contact between the surface of the said plates and the crystals,

means comprising an insulating medium having a low coefficient of friction positioned within the space between said plate and crystal combination and the walls of said cupped member for maintaining said oil film between said plates and crystals, and means providing an air layer back of said inner plate when the space contains said medium and producing a pressure against the back of the inner plate.

12. The combination as defined in claim 11 wherein said second named means comprises a narrow edge extending around the periphery of each plate which edges project out from the surfaces against which the crystals are mounted so as to embrace the crystals to prevent the inner plate from shearing across the outer plate and to maintain the plate-crystal combination in alignment.

13. The combination as defined in claim 11 wherein said last named means comprises a resilient gasket conforming substantially to the shape of the inner plate compressed between the back of the inner plate and the cupped member.

14. In a supersonic signaling device a cupped shaped containing and supporting member, an inner metallic plate, an outer metallic plate, a mosaic of piezo-electric crystals interposed between said plates with their x -axes perpendicular thereto, means comprising an oil film positioned between said plates having a viscosity and capillary activity which produces a change in the thickness of the oil film substantially equal and opposite to the change in thickness of the crystal-plate combination with equal changes in temperature, whereby the overall thickness will remain substantially constant irrespective of operating temperature.

15. In a supersonic signaling device a cupped shaped containing and supporting member, an inner metallic plate, an outer metallic plate, means securing said outer plate to said cupped member, and a mosaic of piezo-electric crystals interposed between said plates, said mosaic comprising a plurality of equal sized similarly shaped crystals having the same angular relation between faces, edges and crystallographic axes, each crystal being arranged with its x -axis perpendicular to the surface of said inner and outer plate and with its y -axis positioned at an angle of ninety degrees relative to the y -axis of an adjacent crystal.

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