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J. H. REAM

2,324,024

PIEZOELECTRIC UNIT

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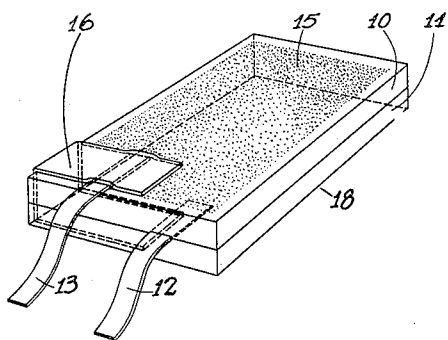


Fig. 1.

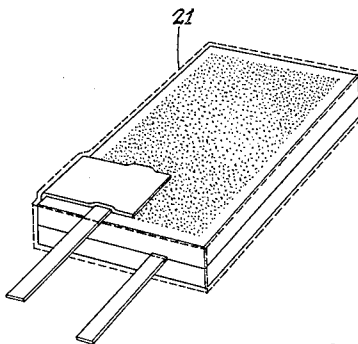


Fig. 2.

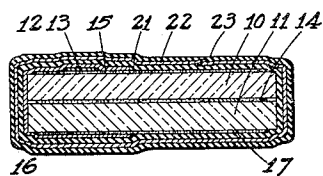


Fig. 4.

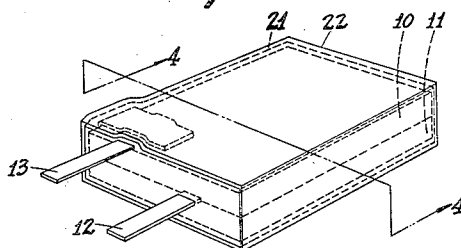


Fig. 3.

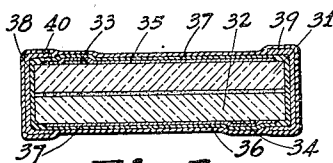


Fig. 5.

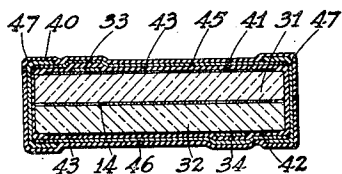


Fig. 6.

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PIEZOELECTRIC UNIT

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Application July 7, 1941, Serial No. 401,318

14 Claims. (Cl. 171—327)

My invention pertains to piezoelectric units and more particularly to means and methods for waterproofing piezoelectric units made of water soluble crystalline material such as Rochelle salt.

An object of my invention is to prevent moisture from spreading on the surface of a piezoelectric crystal plate.

Another object of my invention is to reduce the irregularities on the surface of a piezoelectric crystal to prevent the spread of moisture.

A further object of my invention is to prevent cracking of a foil jacket for a piezoelectric crystal.

A still further object of my invention is to provide an improved method of constructing a piezoelectric unit.

It is also an object of my invention to provide a series connected piezoelectric crystal unit which is waterproofed by a foil covering and by waterproofing material.

Another object of my invention is to provide an effectively electroded piezoelectric unit having a foil waterproofing jacket which is adhered to said electroded unit.

Other objects and a fuller understanding of my invention may be had by referring to the following detailed description and claims, taken in conjunction with the accompanying drawing in which:

Figure 1 is an isometric view of a piezoelectric unit before a waterproof covering has been applied.

Figure 2 is an isometric view of a piezoelectric unit after a waterproof coating has been applied.

Figure 3 is a view of a piezoelectric unit which has been wrapped in a substantially waterproof sheath.

Figure 4 is a cross sectional view taken along line 4—4 of Figure 3.

Figure 5 is a cross sectional view of a series connected piezoelectric unit which has been waterproofed in accordance with my invention.

Figure 6 is a cross sectional view of another form of a series connected piezoelectric unit.

In piezoelectric devices such as pickups, microphones, loudspeakers, etc., which depend for their operation upon a piezoelectric transducer unit, it is essential that moisture be kept from the crystal slabs which, together with the electrodes and the leads, comprise the piezoelectric unit. A slight amount of moisture on the crystal slabs is apt to cause a low resistance shunt circuit which effects a reduction of the output voltage generated in the slabs by a bending or twisting strain, or even a short circuit which will reduce

the output voltage to zero. When reduction of the output voltage takes place the efficiency of the unit is materially reduced. Moisture on the crystal slabs in a motor device establishes a shunt circuit in parallel with the device thereby reducing the impedance. This usually reduces the motion of the device and may also cause heating of the unit. Crystal slabs which are cut from crystals of Rochelle salt will not operate after they have been subjected for an extended period to temperatures in the neighborhood of 130° F., or above. Accordingly heat which is generated in the shunt circuit is apt to destroy the piezoelectric properties of the material. It is, therefore, essential that a piezoelectric crystal unit be waterproofed to prevent the ingress of moisture to the crystal slabs.

Figure 1 illustrates a pair of Rochelle salt crystal slabs 10 and 11 which have been cut from a large Rochelle salt crystal with suitable orientation, electroded, and cemented together with suitable orientation, with an inner lead 12 and an outer lead 13 in place. The electroding may be done in accordance with Alfred L. W. Williams' Patent No. 2,106,143 for Piezoelectric device and method of making the same. The outer lead 13 is held against a graphite electrode 15 by means of a foil strip 16 which is adhered to the crystal slabs 10 and 11, and the inner lead 12 is held against the inner graphite electrode 14 (Fig. 4) by means of the cement which is used to hold the slabs 10 and 11 together.

The inner electrode 14 comprises a thin layer of an electrical conductor such as graphite in close electrical association with the inner surface of the crystal slab 10 and a second thin conductor in close association with the inner surface of the crystal slab 11. The outer surface 15 of crystal slab 10 is graphite electroded and the lead 13 is held in good electrical contact with the electrode by means of the foil strip 16 which is cemented to the lead and to the graphited crystal slab 10. The foil strip 16 is bent around the edges of both of the crystal slabs 10 and 11 and is in electrical contact with a graphite electrode 17 (Fig. 4) on the outer surface of the crystal slab 11 thereby establishing lead 13 as the lead for the outer surfaces of both crystal slabs 10 and 11. This assembly which is illustrated in Figure 1 constitutes an unwaterproofed but operative piezoelectric unit which is ready to be waterproofed in accordance with my invention and which is indicated generally by the reference character 18.

Figure 2 illustrates the piezoelectric unit 18

after it has been coated with a waterproofing material 21 and Figure 3 illustrates the coated unit after it has been wrapped in a waterproof sheath 22 such as tin foil. The wrapping process may be done substantially in accordance with my application for a Piezoelectric unit and method of making same, Patent Number 2,266,333, which describes in detail the method of wrapping the crystal units in an outer electrode. Briefly, in this process a long strip of foil having suitable adhesive applied to one face thereof is stretched out upon a flat surface with the adhesive face uppermost. The crystal assemblies are then placed upon the foil strip. After a suitable number have been so applied, the foil between the crystals is cut thus freeing each assembly from the others, and leaving wide borders of foil on three edges of each assembly. The next step in the process consists in folding the borders and wrapping them about the sides of the assembly. By leaving sufficient foil on the borders the ends will overlap. The final step in wrapping the crystal may be substantially a repetition of the previous step, but in this case the overlapping portion may be placed on the long strip of foil, the foil cut leaving wide borders, and then the borders folded around the edges of the crystal unit into a second overlapping position. In this manner one overlap will be on one face of the crystal and the other overlap will be on another face of the crystal. Obviously many other methods of applying foil to the crystal plates may be used. Figure 4 illustrates the foil wrapped piezoelectric unit of Figure 3 after it has been coated a second time with a waterproofing material 23.

Tests have shown that crystal units which have been waterproofed in accordance with my invention withstand being submerged in warm water for a surprisingly much longer length of time than units constructed according to the prior art. In a test twelve crystal units which were waterproofed according to the prior art viz: a layer of foil next to the crystal slabs and four layers of a waterproofing material on top of the foil, were compared to twelve crystal units which were waterproofed according to my invention viz: two layers of the waterproofing material substantially next to the crystal slabs, a layer of foil, and two more layers of the waterproofing material. To provide an electrode for the twelve units waterproofed according to my invention it was necessary to apply a thin layer of graphite to the top and bottom surface of the crystal slabs. These graphite electrodes are shown as 15 and 17 in Fig. 4. In order to make the test as accurate as possible a layer of graphite was applied to the top and bottom surfaces of the crystal slabs which were waterproofed according to the prior art even though the graphite was not essential to the operation of the unit. The same workman assembled all 24 of the test units and the units were tested to destruction in a warm water tank at the same time. The total thickness of waterproofing material on each unit was held as close to .0032 inch as possible. The units which were waterproofed according to the prior art lasted an average of 55.25 hours and the units which were waterproofed according to my invention lasted an average of 379.33 hours before water inside the coatings rendered them substantially inoperative.

By using a graphite conductor which can be closely applied to the crystal surface, the foil wrap, such as is illustrated in my above mentioned application, is no longer essential as an electrode, but because of its excellent waterproof-

ing qualities I use it between two layers 21 and 23 of waterproofing material such as shellac or lacquer. The waterproofing material is preferably an adhesive applied to the graphited crystal surface in a liquid state and around which the foil sheath 22 is applied after it has become hard enough to enable a person to handle it easily. After the foil sheath has been applied the second coat of waterproofing material 23 which is also preferably an adhesive, is applied. The coat of waterproof adhesive 21 between the foil wrapper 22 and the graphited crystal surface prevents the rapid spread of moisture across the crystal surface if a small moisture passage should develop through the successive waterproof barriers, thereby preventing the rapid formation of shunt circuits. When moisture comes in contact with a water soluble slab of Rochelle salt which has been waterproofed in the usual manner several actions may take place. The water may start dissolving the crystal slab and in time may "eat away" a fairly large piece of the crystal, and the water may spread over the surface of the crystal slab underneath the various layers of waterproofing and in time reach a vulnerable spot such as the part of the crystal unit which is adjacent to the leads or the electrodes, and establish a shunt circuit which reduces the output voltage of the device. The spreading action is usually much more rapid than the dissolving action. During the time that the crystal is being "eaten away" and during the time that the water is spreading over the surface of the crystal, shunt circuits may be set up on the surface of the crystal, and the output voltage generated in the slab by a bending or twisting strain may gradually be reduced until the voltage is too low to be of practical value.

I have found that a generator device will maintain its voltage output at a reasonably high value for a considerable length of time as long as no shunt or short circuit occurs in it, even though considerable of the crystalline material has been eaten away by moisture seeping through the waterproof coating.

Similarly, in motor devices, the establishment of a shunt or short circuit due to moisture is more detrimental to the efficient operation of the device than the water "eating away" part of the crystalline material. However, the dissolving of the crystal slabs in both generator and motor devices may eventually cause the device to become inoperative.

To reduce the occurrence of the more serious of these two effects: i. e., to prevent the spreading of water over the surface of the crystal slab, I apply a coating of waterproof adhesive material to the surface of the crystal to fill in substantially all of the surface pits and irregularities. Around the coating of waterproof material is a jacket of metallic foil (such as tin foil) or other substantially waterproof material. The foil jacket is about .0006 inch thick and may be slightly porous to allow the layer of waterproofing material underneath it to dry out. As the waterproofing material dries out it seals the pores from the underneath surface of the foil, and the outside layer of waterproof material seals the pores in the foil from the outside surface thereof and establishes a substantially water resistant barrier.

By preventing the spread of moisture across the crystal slab surface the amount of water which may enter through the passage is limited, thereby reducing the rate at which the water

dissolves the soluble Rochelle salt crystal. If water was allowed to spread freely across the surface of the crystal slab a larger quantity of water would enter through a small hole in the protective waterproof coating and a much larger amount of the Rochelle salt would go into solution. By restricting the moisture after it penetrates the waterproof coating only a relatively small localized portion of the Rochelle salt crystal will be in contact with the water, and after that small portion has been dissolved the concentration of the solution will approach saturation and limit the rate at which more salt goes into solution. Accordingly the presence of the waterproof adhesive material between the foil and the crystal slab retards the rate at which water spreads over the surface of the crystal slab, reduces the amount of water which enters through a hole in the waterproof covering, and reduces the rate at which the soluble Rochelle salt enters in to solution with the water which may enter through the hole in the waterproof covering.

The waterproof covering for a piezoelectric unit cannot be too thick or stiff or it adversely affects the operation of the device with which the unit is associated. Accordingly the amount of waterproofing which can be applied to a unit is limited and the most effective protection for a given amount of waterproofing material becomes highly desirable.

The electrical leakage resistance in a piezoelectric unit is high until a small amount of moisture comes in contact with a fairly large area of the surface of the crystal, then the resistance drops quickly. An unelectroded and unwaterproofed unit which has a lead at each end may have a leakage resistance on the order of several thousand megohms. When a person breathes on the crystal slab the resistance drops in a few seconds to the order of about $\frac{1}{4}$ megohm even though no appreciable amount of the crystal has been dissolved in the moisture from the breath. It will be seen, therefore, that a very small amount of moisture spread over the surface of the crystal slab will materially affect the unit.

To obtain the maximum amount of protection against moisture without stiffening the crystal unit too much, I have found that two coats of waterproofing material applied over the graphitized crystal unit and averaging about .0006 inch in thickness, one layer of a waterproofing material such as tin foil about .0006 inch in thickness, and two final coats of waterproofing material applied over the foil sheath and averaging about .0007 inch in thickness provide an excellent resistance to the ingress and spreading of moisture without objectionably stiffening the unit which is about .06 inch thick. It is to be remembered, however, that the amount of stiffening which can be tolerated depends upon the size of the crystal slabs which are to be used in the unit, and that ordinarily the larger the slabs the more layers of waterproofing may be applied without seriously affecting the operational characteristics of the device.

Another important feature of my invention is the rounding of the sharp edges of the crystal slabs by the several layers of waterproofing material before the foil is applied. When the foil is applied in close engagement with the crystal slabs, the sharp edges and corners of the slabs are apt to break the foil and provide moisture with easy means of access to a vulnerable area. By applying several layers of waterproof material the sharp edges and corners of the crystal

slabs are rounded and a cushion is provided between the foil and the crystal. This materially reduces the probability that the foil will break when it is bent around the edges and corners of the crystal and helps to increase the life of the unit before it fails due to the presence of moisture inside the waterproof coatings.

Figure 5 illustrates my invention applied to a series connected unit comprised of two crystal slabs 31 and 32 having leads 33 and 34 on opposite outside surfaces thereof. Two graphite or tin foil electrodes 35 and 36 engage the leads 33 and 34 and the surfaces of crystals 31 and 32 respectively, but do not extend around the corners of the crystal slabs.

Outside of the electrode there is a layer of waterproof adhesive material 37, and outside of the adhesive material there are edge strips of waterproofing material such as tin foil for moistureproofing the edges and end of the unit. These strips 38 and 39 may overlap the foil electrodes 35 and 36 to provide in effect a jacket or sheath for the crystal slabs. A final layer of waterproofing material 40 may then be added to the unit. It will be seen that along the edges where shunt circuits are apt to form if moisture is present there is a waterproof adhesive layer between the edge protecting means 38, 39 and the crystal slabs 31, 32. Moisture is therefore prevented from spreading if it breaks through the successive barriers of waterproof material.

Figure 6 illustrates a form of a series connected unit in which graphite electrodes 41 and 42 are applied to the outside surfaces of the crystal slabs 31 and 32 and in engagement with leads 33 and 34 respectively. A coating of adhesive waterproofing material 43 is added to the unit and then top and bottom foil waterproofing means 45 and 46 are added. Edge waterproofing means 47 of material such as cellulose acetate may then be applied in overlapping engagement with the foil 45, 46, or may be wrapped entirely around the unit, and one or more layers of waterproof material 40 are then applied around the outside of the assembly. Either of these constructions prevents the spread of moisture across the crystal surface.

The foil which is used to electrode the units and to moistureproof them is slightly porous to facilitate the drying of the waterproofing adhesive material which is between the foil and the crystal surface. As the adhesive material dries out it seals the pores from the inside, and as the outside layer of adhesive waterproofing material dries out it seals the pores from the outside.

Tests have shown a remarkable improvement in units waterproofed in accordance with the foregoing description over units waterproofed in accordance with previous practice, and I believe from my experience with these crystal units that the theories set forth in this specification explain the causes for the improvement although other factors than those set forth and which at this time are not apparent may contribute to the excellence of the product.

Although I have described my invention with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim as my invention:

1. A substantially moistureproof covering for a water soluble crystal unit comprising, in combination, a surface coating of substantially moistureproof material adhered to said crystal unit, substantially moistureproof foil means around said surface coating, and an outer coating of substantially waterproof material around said foil means; said outer coating, said foil means, and said surface coating establishing respectively first, second and third barriers to the passage of water to the crystal, and said surface coating preventing the spreading of moisture between the said crystal unit and the said foil means.
2. A piezoelectric device comprising crystalline plate means of water soluble Rochelle salt, a graphite electrode in intimate engagement with said plate means, foil means wrapped about said piezoelectric device and adapted to protect said plate means from moisture, waterproof means between said graphite electrode and said foil wrapper and in adhesive engagement with each to prevent moisture which is apt in time to penetrate said foil wrapper from spreading between said graphite electrode and said foil wrapper.
3. In a moistureproof coating for a piezoelectric unit having a substantially waterproof wrap through which in time moisture is apt to pass to the detriment of the said unit, moisture resistant adhesive means entirely covering the unit and located between said unit and said substantially waterproof wrap to substantially prevent the spread of moisture therebetween to localize and retard the detrimental effect of the said moisture.
4. A substantially moistureproof covering for a water-soluble Rochelle salt crystal unit comprising, in combination, a first coat of substantially moistureproof material around and adhered to said crystal unit, foil means wrapped around said moistureproofing material and establishing a second substantially moistureproof coat, a third coat of substantially moistureproof material around and adhered to said foil means, said first coat of substantially moistureproof material resisting the spreading of moisture between the foil means and the crystal unit if moisture breaks through the third and second substantially moistureproof coats.
5. The process of waterproofing a piezoelectric unit which comprises the steps of coating the said unit with a substantially waterproof material to entirely cover the unit, and wrapping said unit and said waterproof material in a substantially waterproof covering, said waterproof material substantially preventing the spread of water between the said unit and the said cover.
6. The process of waterproofing a piezoelectric unit which comprises the steps of adhering a substantially waterproof material to the entire surface of the said unit, and wrapping said unit and said adhered waterproof material in a substantially waterproof covering, said adhered waterproof material substantially preventing the spread along the surface of the said unit, of water which in time is apt to seep through the said substantially waterproof covering.
7. The process of constructing a piezoelectric unit comprising the steps of providing a plate assembly which includes a plurality of crystalline plates connected together and having first electrode means and first lead means therebetween; applying graphite second electrode means to the said plate assembly; connecting second lead means to the said plate assembly and in engagement with the said graphite electrode by means of a conductor strip having adhesive thereon; covering the said plate assembly, the said graphite second electrode, the said conductor strip, and a portion of the said lead means with a first coat of substantially waterproof material; applying a substantially waterproof jacket to said covered plate assembly; and covering said jacket with a second coat of substantially waterproof material.
8. A piezoelectric device comprising crystalline plate means of water soluble Rochelle salt, electrode means associated with said Rochelle salt plate means, a substantially waterproof wrapper for said plate means and said electrode, and means between said substantially waterproof wrapper and said electrode and entirely covering said electroded plate means to localize the effect of moisture which in time is apt to pass through the said substantially waterproof wrapper.
9. A waterproof covering for an operative multiple plate series connected piezoelectric unit having a pair of electroded faces and unelectroded edge faces, comprising, in combination, a pair of foil sheets secured one to each of the electroded faces, edge foil means covering said edge faces, and waterproofing means around said unit and positioned between said edge foil means and said foil sheets.
10. An improved series connected piezoelectric crystal unit comprising, in combination, an operative multiple-plate piezoelectric unit having a pair of electroded outer major faces with unelectroded edge faces and having a pair of engaging major faces, a pair of leads secured one to each of the outer major faces, a pair of substantially waterproof foil electrodes secured one to each of the outer major faces and engaging said leads to hold said leads to said major faces, a first coat of waterproofing material around said unit, a second coat of waterproofing material around said unit, and foil means positioned between said first and said second coats of waterproofing material and covering said unelectroded edge faces.
11. An improved series connected piezoelectric crystal element comprising, in combination, an operative multiple plate piezoelectric unit having a pair of electroded outer major faces with unelectroded edge faces and having a pair of engaging major faces, electrode means on the said outer major faces, lead means engaging said electrode means, a coating of waterproofing material around said unit, first foil means engaging said coating of waterproofing material and constituting a waterproofing layer protecting said outer major faces, waterproofing means covering said unit and said first foil means, second foil means covering said edge faces and overlapping said first foil means to establish substantially a foil sheath for said unit, and waterproofing means covering said unit and said second foil means.
12. In a substantially moistureproof covering for a piezoelectric unit having a crystalline slab with sharp edges and corners, a substantially moistureproof jacket adapted to be wrapped around said crystalline slab and subject to detrimental effects due to said sharp edges and corners, and guard means positioned between said crystalline slab and said substantially moistureproof jacket for reducing said detrimental effects.
13. In a substantially moistureproof covering

for a piezoelectric unit having a crystalline slab of Rochelle salt with sharp edges thereon, a substantially moistureproof foil jacket around said crystalline slab and subject to detrimental puncturing and cracking due to said sharp edges, and moistureproof means positioned between said crystalline slab and said foil jacket for rounding said sharp edges thereby reducing the amount of said detrimental puncturing and cracking.

14. In a substantially moistureproof covering for a piezoelectric unit having a crystalline slab of water soluble Rochelle salt with sharp

5 edges thereon, a substantially moistureproof jacket around said crystalline slab and subject to detrimental puncturing and cracking due to said sharp edges, and moistureproof means positioned between and adhered to said crystalline slab and to said substantially moistureproof jacket for rounding said sharp edges of said slab thereby reducing the amount of said detrimental puncturing and cracking, and thereby substantially preventing the spread of moisture on said crystalline slab.

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