

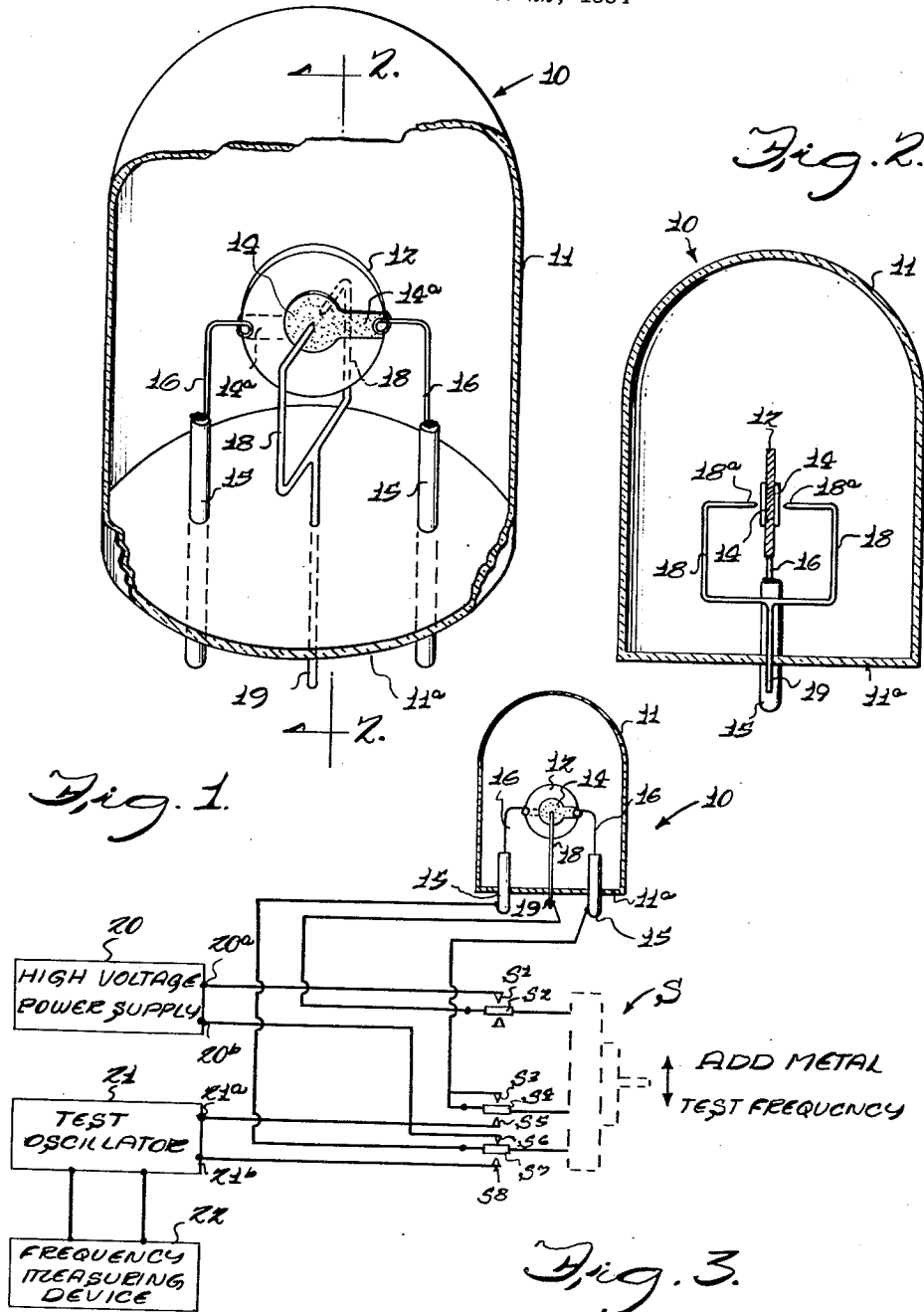
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SEALED CRYSTAL ASSEMBLY

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SEALED CRYSTAL ASSEMBLY

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6 Claims. (Cl. 310—8.1)

The present invention relates in general to piezoelectric crystals of the type used, for example, as frequency determining and stabilizing elements for electronic oscillators; it relates in particular to sealed crystal assemblies in which the crystal frequency may be precisely adjusted after the envelope sealing is complete.

It is the general aim of the invention to provide an extremely compact sealed crystal assembly having improved means for precisely lowering the crystal frequency, after the envelope is sealed, by electrical discharge which "sputters" metal onto the crystal.

Concurrent with that aim, another object of the invention is the provision of such a compact crystal assembly in which metal is uniformly added to coatings on both sides of the crystal, producing reliable adjustment of frequency and in a very short time. The temperature of the crystal thus remains substantially constant in view of the short periods during which it is subjected to ion bombardment.

It is a further object to make possible the "sputtering" of metal onto a crystal in a sealed envelope by applying an alternating voltage, rather than a direct voltage.

Other objects and advantages will become apparent as the following description proceeds, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a perspective view, drawn partially in section for clarity, of an exemplary crystal assembly embodying the features of the invention;

Fig. 2 is a vertical transverse section of the assembly, taken substantially along the line 2—2 in Fig. 1; and

Fig. 3 is a longitudinal vertical section of the crystal assembly, shown together with a schematic representation of exemplary apparatus employed with the assembly for final frequency adjustments.

While the invention has been shown and is described in some detail with reference to a particular embodiment thereof, there is no intention that it thus be limited to such detail. On the contrary, it is intended here to cover all modifications, alternative constructions and equivalents falling within the spirit and scope of the invention as defined by the appended claims.

Referring now to the drawing, the invention has been illustrated as embodied by a crystal assembly 10 which in this instance includes a glass envelope 11 exhausted to a vacuum on the order of 100 microns. A crystal 12 of any well known type, such as an accurately cut wafer of natural or synthetic quartz, is located within the envelope 11 and provided with metallic coatings 14 on its opposite faces. As is well known, the size of the crystal, the manner in which it is cut relative to its crystalline structure, and the extent and thickness of the metal coatings 14 all combine to determine the natural frequency of operation. The metal coatings thus serve not only as convenient means for making electrical connections to the opposite faces of the crystal, but also serve as a means for effecting changes in the natural frequency of the crystal.

For supporting the crystal 12 within the envelope and at the same time providing electrical connections to the

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coatings 14 from the exterior of the envelope, a pair of connectors are provided which include rigid metallic stems 15 sealed through a lower press portion 11a of the envelope and carrying resilient wires 16 welded to their upper ends. The wires 16 are formed with tight spirals at their upper ends which are adapted to clip over diametrically opposite edge portions of the crystal. The wires 16 thus afford a shock-proof mount for the crystal, and the spiral clips provide electrical connections to the coatings 14 by engagement with radial extension 14a of the respective coatings.

It has been a well known practice to mount piezoelectric crystals in sealed and preferably evacuated envelopes to exclude foreign matter from the crystal surfaces and to substantially eliminate the effects of changing pressure, humidity and temperature on the natural frequency of the crystal as it is employed under a wide variety of atmospheric conditions. While, as noted above, the natural frequency of the crystal may be controlled by carefully determining its size and the thickness of the metal coatings during manufacture, some change of this natural frequency inevitably occurs as an incident to mounting of the crystal in the clip wires 16, exhausting the envelope 11, and sealing the latter. It thus becomes desirable to provide some means for precisely adjusting the natural frequency of the crystal to the exact value desired after the envelope 11 is sealed. If, after the envelope is complete, the crystal's frequency is too low, small amounts of the metal coatings may be removed from the crystal by the method described and claimed in the present inventor's copending application Serial No. 464,088 filed October 22, 1954. The present invention is particularly concerned with providing a crystal assembly which permits the natural frequency of the crystal to be reduced, after the envelope is sealed, to the exact value desired. By constructing a crystal assembly as herein described and using either the present method to decrease the crystal frequency, or the method set forth in the above-mentioned copending application to increase the crystal frequency, all crystal units coming from an assembly line may be finally adjusted to a precise frequency whether the sealing of the envelope finds them above or below that desired frequency.

In accordance with the present invention, means are disposed within the envelope 10 for effecting by electric discharge the controlled additional deposit of metal on the coatings 14 in response to the application of a suitable voltage or potential between two external points after the envelope 11 is sealed. This, of course, increases the thickness of the metal coatings 14 and decreases the natural frequency of the crystal 12. Such means preferably takes the form of an auxiliary electrode disposed opposite the crystal coating and having an area facing the coating which is small relative to the area of the coating. Ideally, the auxiliary electrode is a pointed metal projection disposed opposite the crystal coating within the envelope 11 at the time of its manufacture and provided with suitable means extending through the envelope to afford external electrical connection thereto.

As here shown, such pointed metal projection is made in the form of a pair of fine gauge wires 18 supported within the envelope 11 so as to embrace the crystal 12, these wires having their upper ends 18a turned inwardly so as to be closely spaced from but pointing toward the respective coatings 14. In order to both support the wires 18 and afford external electrical connection thereto, a frangible terminal wire 19 is extended in sealed relation through the lower press portion 11a of the envelope. Preferably, the wires 18 are made of the same material as the metal coatings 14, although this is not vitally necessary. Gold or silver are most often applied for the coatings 14 and in these cases it is desirable that the wires 18 be made of the

same metal. While the arrangement of the auxiliary electrode and the external terminal means therefor may take a variety of configurations, those shown in the present case may be characterized as having a shape in the nature of a "wishbone."

With the assembly thus formed prior to the evacuation and sealing of the envelope 11, it is but a simple matter to effect controlled increases in the natural frequency of the crystal 12 after the envelope has been sealed. The manner in which such adjustments of the crystal frequency are made may be best explained with reference to Fig. 3, which diagrammatically illustrates the crystal assembly 10 having its stems 15 and terminal element 19 connected in circuit with a high voltage power supply 20, a test oscillator 21, and a frequency measuring device 22 through the medium of a three pole, double throw switch S. Assuming that the natural frequency of the crystal is originally higher than that desired, movement of the switch S to its upper position causes the switch contacts S₁, S₂ to connect the terminal 29a of the power supply 20 to the external terminal 19 for the wires 18; simultaneously, the switch contacts S₃, S₄ and S₆, S₇ connect the stems 15 in parallel to the other terminal 20b of the power supply 20. As a result, an electrical discharge is created between the ends 18a of the wires 18 and the respective metal coatings 14, the pointed ends of the wires serving as cathodes and the coatings 14 serving as anodes. Accordingly, metal is sputtered from the wire tips and deposited on the coatings 14 as an incident to such discharge.

While the power supply 20 may provide a direct voltage, with the positive terminal connected to the coatings 14 and its negative terminal connected to the wires 18, it has been found that the present invention permits the use of an alternating voltage power supply of relatively high frequency. The desired action, i. e., the transfer of metal from the wires 18 to the coatings 14, is obtained with an applied alternating voltage by virtue of the fact that the sharp ends 18a have such a small area facing the coatings, relative to the area of the coatings themselves, that they cause point rectification to occur. That is, discharge current flows more readily on half cycles of the voltage which make the wires 18 negative with respect to the coatings than on opposite half cycles, so that the net transfer of metal is from the wires 18 to the coatings. There is thus no appreciable reverse transfer of metal from the coatings 14 to the wires 18.

The magnitude of the voltage supply taken from the power supply 20 may vary over a wide range depending upon the degree of vacuum in the envelope 11, the relative spacings between the coatings 14 and the wire tips 18a, and whether the applied voltage is direct or alternating. It has been found that a direct voltage in the order of 200 to 600 volts is usually sufficient, while an alternating voltage of 2500 volts at a frequency of 30 kc. per second also produces satisfactory transfer of metal.

After the switch S has been held in its upper position for a few seconds, it is depressed to its lower position to thereby cause the switch contacts S₄, S₅ and S₆, S₇ to connect the respective stems 15 to the terminals 21a and 21b of the test oscillator 21. This establishes the crystal 12 as the frequency controlling element of the test oscillator, and the natural frequency of the crystal may therefore be observed on the frequency measuring device 22. If the crystal's frequency is still above the value desired, the switch S is shifted again to its upper position for a few seconds to cause additional transfer of metal to the coatings 14 by electric discharge. The switch is then reversed to measure the crystal's frequency a second time. This procedure may be repeated until the natural frequency of the crystal is decreased to precisely the value desired. The whole operation takes but a few seconds.

After the exact frequency for the crystal 12 has been attained, the frangible terminal wire 19 for the wires 18 may be broken off at its point of projection through the press portion 11a. Thus, the crystal assembly is com-

pleted without leaving an interfering auxiliary terminal extending from the envelope; and this also precludes the inadvertent change of the crystal's frequency from the value to which it has been adjusted.

While the drawings presently referred to are made to a large scale, it is to be understood that in many types of crystal assemblies the envelope 11 is no larger than an ordinary acorn. The present construction utilizing the fine gauge wires 18 permits the above described precise increases in the crystal's frequency without requiring any appreciable additional space within the envelope 11. Since the auxiliary electrode is formed as a pair of wires respectively pointing toward the two metallic coatings 14, the application of a potential difference between the coatings 14 and the wires 18 causes additional metal to be uniformly sputtered onto both of the coatings. This produces a more reliable decrease in the crystal's frequency and permits such decrease to be obtained with greater rapidity.

Since it is necessary to hold the switch S in its upper position for only a few seconds at a time, the crystal 12 is not appreciably heated by ion bombardment incident to the resulting electrical discharge. Accordingly, when the crystal frequency is measured by the test oscillator and frequency measuring device 22, no temperature correcting factor need be considered. Moreover, since the sharp wires 18 result in a point rectification effect, an alternating potential is conveniently and reliably employed to cause the sputtering action described. This is of importance since it is much more convenient to obtain a relatively high alternating potential by transformer action than to obtain a correspondingly high direct potential.

If the crystal's frequency after the envelope is sealed is initially too low, the method described in the above-mentioned copending application may be employed to remove small amounts of metal from the coatings 14 and to thus precisely bring the crystal's frequency to the value desired. The auxiliary electrodes or wires 18 in no way interfere with this method. On the other hand, if the crystal's frequency is initially too high after the envelope 11 is sealed, apparatus such as that shown in Fig. 3 may be used as described to effect discharge between the auxiliary electrodes or wires 18 and the metal coatings 14. This causes controllable transfer of metal from the auxiliary electrodes to the coatings 14 and may thereby be used to precisely decrease the crystal's natural frequency to the desired value. Thus, crystal assemblies of the type herein described coming from a production line may be accurately adjusted to a given desired frequency providing the initial frequency is not too far displaced above or below the frequency desired.

I claim:

1. In a crystal assembly, the combination comprising a sealed envelope, a crystal having metal coatings on its opposite faces, means for mounting said crystal within said envelope and for affording external electrical connection to said coatings, a pair of wires mounted within said envelope and having their respective ends closely spaced from and pointing toward the respective coatings, and means for affording external electrical connection to said wires.

2. In a crystal assembly, the combination comprising a sealed glass envelope, a crystal having metal coatings on its opposite faces, a pair of connectors extending through said envelope and serving to mount the crystal therein while affording external connection to respective ones of said coatings, a pair of fine gauge wires in said envelope embracing said crystal and having their respective ends closely spaced from and pointing toward said coatings, and a frangible terminal wire connected to both of said wires and extending in sealed relation through said envelope.

3. In a crystal assembly which includes a sealed envelope containing a crystal having metal coatings on its opposite faces and connectors extending from said coat-

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ings to the exterior of the envelope, that improvement which comprises a pair of fine gauge wires embracing said crystal and having their ends turned inwardly toward but spaced from respective ones of the coatings, and a frangible terminal wire supporting said pair of wires and extending through the envelope for external electrical connection.

4. A crystal assembly susceptible of adjustment in operating frequency by the application of an alternating voltage thereto, said assembly comprising an hermetically sealed envelope, a crystal mounted therein and having a metallic coating on its opposite faces electrically connected with leads extending through the envelope, a pointed metal projection within the envelope and extending generally toward one crystal coating but spaced therefrom, and means exterior of the envelope for establishing electrical connection to said projection to afford external application of an alternating voltage between said projection and the coating which creates a point-rectified discharge which sputters metal from the projection to the coating.

5. In a crystal assembly including an hermetically sealed envelope, a crystal mounted therein and having a metallic coating of a given area on its surface electrically connected with a lead extending through the envelope, that improvement for making possible reduction of the crystal's operating frequency by application of an alternating voltage source and which comprises an auxiliary electrode disposed within said envelope opposite said

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metal coating, said auxiliary electrode having an effective surface area facing said coating which is very small relative to said given area, and means extending through said envelope for establishing external electrical connection to said auxiliary electrode, whereby the application of said alternating voltage source between said last-named means and said leads creates a discharge between said auxiliary electrode and said coating resulting in a net transfer of metal from the former to the latter and a decrease in the crystal's frequency.

6. In a crystal assembly including an hermetically sealed envelope, a crystal mounted therein and having a metallic coating of a given area on its surface electrically connected with a lead extending through the envelope, that improvement which comprises an auxiliary electrode disposed within said envelope opposite said metal coating, said auxiliary electrode having an effective surface area facing said coating which is very small relative to said given area, and means extending through said envelope for establishing exterior electrical connection to said auxiliary electrode.

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