Jan. 27, 1931. R. C. HITCHCOCK 1,790,148

OSCILLATION GENERATOR

Filed March 25, 1927

Fig.1.

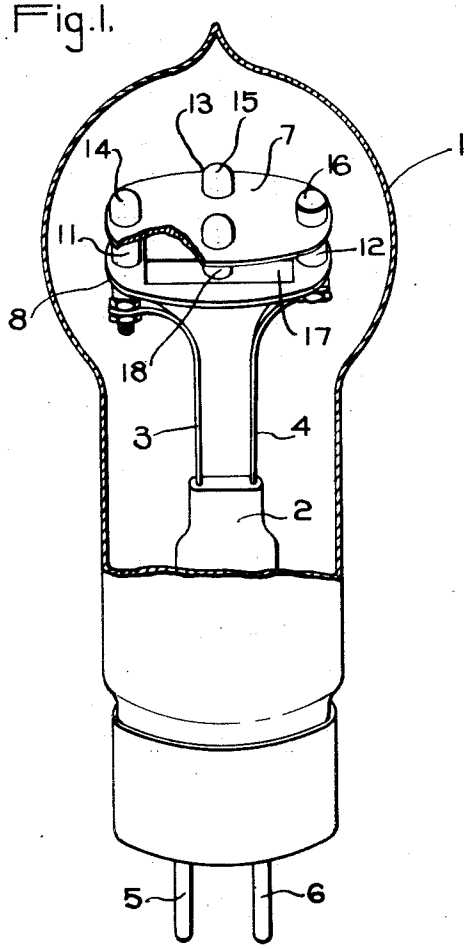


Fig.5.

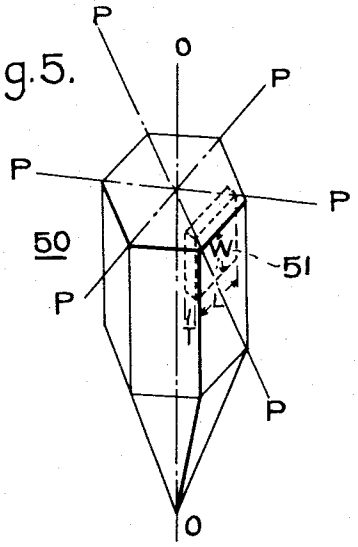


Fig.2.

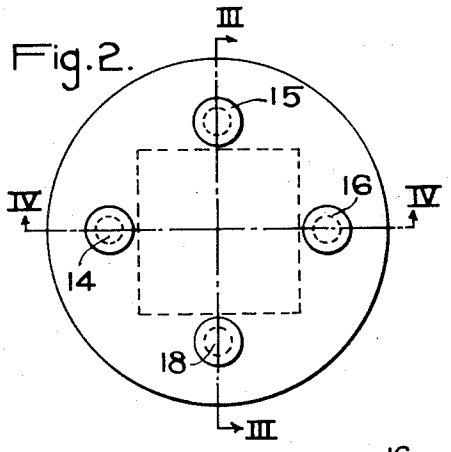


Fig.3.

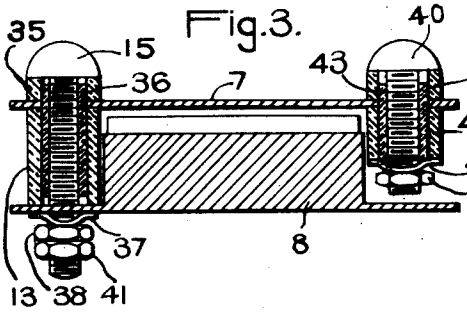
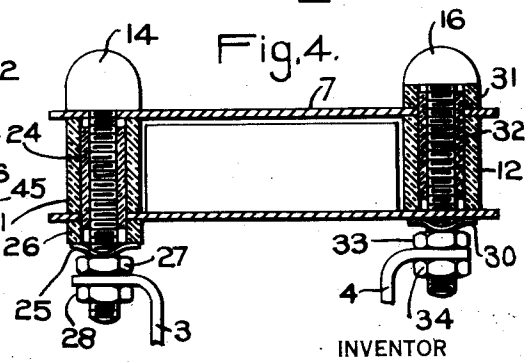


Fig.4.



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UNITED STATES PATENT OFFICE

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OSCILLATION GENERATOR

Application filed March 25, 1927. Serial No. 178,235.

My invention relates to oscillation generators and more particularly to oscillation generators in which piezo-electric crystals are utilized to control the frequency thereof.

One object of my invention is to provide, in a system of the type described, means for materially increasing the power-controlling capability of a piezo-electric crystal.

Another object of my invention is to provide a crystal housing and supporting device that reduces the likelihood of crystal breakage during use.

Another object of my invention is to provide a crystal-mounting device that shall not be subject to deterioration.

Another object of my invention is to provide a crystal-mounting device that prevents substantially all sparking across the crystal supported thereby, when such crystal is being utilized to control the output of an oscillation generator.

Another object of my invention is to provide a crystal-mounting device that is rigid and substantially unaffected by temperature variations.

Another object of my invention is to provide a method whereby the oscillation frequency of a piezo-electric crystal may be accurately predetermined.

Another object of my invention is to provide a method for accurately predetermining the optimum spacing to be employed between a given crystal and a cooperating electrode.

A still further object of my invention is to provide, in a system of the type described, means whereby a piezo-electric crystal may be accurately maintained in the optimum position with respect to the electrodes cooperating therewith, for maximum power output.

The use of piezo-electric crystal sections for the control of thermionic oscillation generators has become practically universal in radio transmitting systems designed to maintain a constant radiation frequency.

Previous workers in the art, as, for example, Nicolson, Cady and Hund, have devised a large number of circuits adapted to so interconnect a piezo-electric crystal section and a thermionic device that oscillations of constant frequency may be maintained therein, all of such circuits necessitating the support of the crystal section between a plurality of electrodes constituting a condenser. The condenser, having the crystal section as a portion of its dielectric, is preferably connected between the grid and filament of a thermionic device. The plate, or output circuit of the thermionic device is tuned to approximately the natural oscillation frequency of the crystal. Upon energization of the device, oscillations of crystal-frequency are established, and are maintained at a substantially constant frequency as long as the thermionic device is supplied with filament and plate potentials.

It has been noted, however, that, when the plate potential is made sufficiently high to give a substantial power output, sparking will take place across the crystal between the supporting electrodes. This sparking causes the formation of ozone which attacks the metallic portions of the crystal-section holder, and the heat evolved is often sufficient to cause the section to crack.

The tendency toward destructive sparking I have eliminated by providing the crystal sections with a metallic coating, preferably by electro-plating. In addition, in order to obviate deterioration of the holder from oxidation, I preferably form the electrodes and associated metallic elements from a non-oxidizing material, and support the assembly of crystal and electrodes in a rarefied, inert gas.

Among the novel features of my invention are those particularly set forth in the appended claims. The invention in its generic aspect, however, as well as further objects and advantages thereof, will best be understood by reference to the following description of certain specific embodiments, taken in connection with the accompanying drawings, in which

Figure 1 is a perspective view of a preferred form of mounting device, portions thereof being broken away to more clearly show the relation between the crystal section and the cooperating electrodes;

Fig. 2 is a top plan view of the crystal-sec-

tion-supporting portion of the mounting device;

Fig. 3 is a sectional view of a modified form of crystal-section-supporting assembly, taken along a line corresponding to the line III—III of Fig. 2;

Fig. 4 is a sectional view taken along a line corresponding to the line IV—IV of Fig. 2;

Fig. 5 is a perspective view of a quartz crystal, illustrating the manner in which a crystal section may be cut therefrom.

Referring specifically to Fig. 1, a preferred form of my crystal-section-mounting device, comprises a glass container 1, provided with an electrode-supporting press 2, through which extend lead-in wires 3 and 4 connected to appropriate external contact elements 5 and 6. The elements of my device in intimate contact with the crystal-section comprise an upper plate 7, and a lower plate 8, preferably of stainless iron, Monel metal, or nickel, maintained in fixed parallel relation by a plurality of insulating spacer elements 11, 12 and 13 encircling a plurality of assembly bolts 14, 15 and 16, respectively. The spacer elements are of such a thickness that the upper plate 7 is firmly held a definite distance away from a crystal-section 17, and parallel to the upper face thereof, and are preferably of silica or fused quartz.

The lead-in wire 4 is arranged to make conductive contact with the lower plate 8, and the lead-in wire 3 is conductively connected to the upper plate 7, as shown in detail in Fig. 4, while the crystal-section is prevented from dropping out from between the two plates by an abutment element 18, more clearly shown in Fig. 3.

Referring specifically to Fig. 4, the relative proportions of which are greatly exaggerated in order to more clearly illustrate certain details thereof, and to Fig. 2, it will be noted that the electrodes 7 and 8 are provided with a plurality of openings through which extend the assembly bolts 14, 15 and 16, respectively. The head of the assembly bolt 14 makes conductive contact with the upper plate 7, while the shank thereof is insulated from the lower plate by an insulating sleeve 24. The insulating spacer element 11 surrounds the sleeve 24 and maintains the two plates 7 and 8 a fixed distance apart, pressure being applied to the lower plate through a spring washer 25 abutting an insulating sleeve 26, by means of a nut 27. The lead-in wire 3 is provided with an upper flattened portion having an opening through which passes the lower end of the assembly bolt 14, a second nut 28 serving to maintain the wire in adjusted position.

The relation of the assembly bolt 16 to the two electrodes is substantially the reverse of that of the bolt 14, the head thereof being insulated from the upper plate by a sleeve 31 of pyrex or analogous material and the shank being insulated from the same plate by insulating sleeve 32. The spacer element 12 surrounds the insulating sleeve 31, and, in order to maintain the plates in fixed relation, pressure is applied to the lower plate through a spring washer 30 in contact therewith and held in position by a retaining nut 33. The upper end of the lead-in wire 4 is flattened and is provided with an opening to accommodate the projecting lower end of the assembly bolt 16, on which it is retained by a nut 34.

In actual practice, the vertical distance between the two plates may be made as small as desirable, although when extremely thin crystal sections are employed, it is preferable to utilize a modified lower plate, as shown in Fig. 3. Fig. 3 is not, strictly speaking, a sectional view taken along the line III—III of Fig. 2, but, inasmuch as the assembly bolts and the abutment 18 are the same in either modification, this should cause no confusion.

Referring specifically to Fig. 3, the head of the assembly bolt 15 is insulated from the upper electrode 7 by a sleeve 35 of pyrex or analogous material, and the shank thereof is insulated from the same electrode by another sleeve 36. The spaced element 13 surrounds the sleeve 36 and maintains the electrodes in fixed relation, pressure being applied to the lower plate through a spring washer 37 held in position by a plurality of nuts 38 and 41.

In order to minimize the electrostatic field which will exist between the abutment member 18 and the crystal-section, it is considered preferable that a bolt 40, which supports it from the upper electrode 7, shall be insulated therefrom. To this end, the head of the bolt is prevented by an insulating sleeve 42, from making contact with the upper plate, and a second insulating sleeve 43 is provided to prevent the shank from making contact therewith. The second sleeve 43 is surrounded by a spacer element 44 which abuts the lower surface of the upper plate, the assembly of sleeve and spacer element being held in position by a lock nut 45. If the crystal is intended to control a relatively large amount of power, and, consequently, is subject to heating, the abutment member may also be provided with a spring washer 46 to obviate breakage of the insulating sleeves.

An important feature of the electrode-spacing arrangement just described is the three-point support of the plates relative to each other. As is well known, a plane surface is determined by any three points, and, for this reason, small inequalities in the lengths of the spacing members 11, 12 and 13 will not cause warping of either of the plates when they are drawn tightly against the spacer elements by the retaining nuts.

As has been previously explained, destructive sparking across the crystal section may be substantially eliminated by the applica-

tion to the section of a metallic coating, preferably by electro-plating. In addition, it is thought best to entirely remove all oxygen from the container in order that the formation of ozone shall be prevented, even if a certain amount of sparking occurs. After assembly, therefore, the container is thoroughly evacuated, while being heated to a temperature somewhat less than 585° centigrade. A non-oxidizing gas, such as neon, argon, helium or hydrogen, is then introduced at a pressure of approximately 1/76th of an atmosphere, and the container is sealed off.

It is very important that the spacing between the upper electrode and the crystal be accurately predetermined if maximum output is to be obtained. By research and experiment, I have established the fact that the spacing should never be an integral number of air-wave lengths of the frequency at which the crystal section is intended to oscillate. If the spacing is an integral number of air-wave lengths, it appears that standing waves are set up in the gas between the upper crystal face and the lower surface of the upper plate, resulting in a material decrease in the power output of the oscillator controlled thereby.

The length in millimeters of an air-wave and the frequency in kilocycles per second are related by the equation

$$\text{wavelength (mm)} = \frac{331}{\text{frequency (kc.)}}.$$

This equation is correct to about 1/3 of one per cent for frequencies ranging from 0 to 1500 kilocycles per second at 0° C. temperature. The wavelength is substantially independent of the pressure of the gas being employed but changes slightly with changes in temperature.

For example, if the crystal is ground to oscillate at 662 kilocycles, the air wavelength would be

$$\frac{331}{662} \text{ or } 0.5, \text{ millimeters.}$$

In such event, the upper electrode should not be spaced from the crystal section by any multiple of 0.5 millimeters but should be at a distance of 0.3 or 0.7 millimeters therefrom if maximum output is to be obtained. Such spacing may be very accurately obtained by merely grinding the spacer elements to the proper length, and it will not change any substantial amount during the operation of the device, if made of any of the materials previously referred to.

Still another element must be considered if maximum output is to be obtained from a crystal section at any definite frequency, and that is the fact that crystals intended to have natural frequencies between 300 kilocycles and 30,000 kilocycles should be so cut that very definite relations exist between certain of the dimensions thereof. The optimum ratios between the critical dimensions of a crystal section are extremely important, inasmuch as strict adherence thereto permits the crystal to control much more power than equivalent sections cut according to the teachings of the prior art. In order that this phase of my invention may be more clearly understood, attention should now be directed to Fig. 5.

In Fig. 5, a quartz crystal 50, having a principal optical axis O—O, and a plurality of piezo-electric axes P—P is illustrated. A crystal section 51, having the shape of a rectangular parallelepiped with a length L, a width W and a thickness T, may be so cut from the crystal that the width, W, is parallel to the optical axis, while the length, L, and thickness, T, may be given any desired orientation, just so long as they are kept perpendicular to the face W.

It is generally considered preferable to so arrange the crystal with respect to the supporting electrodes that it will vibrate in the thickness direction, T, the vibration frequency then being determined by the thickness. I have discovered that the power output of the oscillation generator controlled by such a crystal is a maximum for two ranges of the ratio of L to W. These ranges are as follows:

1. When $\frac{L}{W}$ lies between 0.7 and 0.9.

2. When $\frac{L}{W}$ lies between 1.1 and 1.4.

It is not particularly important that the two L faces shall be absolutely parallel, nor is it necessary that the two W faces be parallel, slight tapering or beveling thereof being permissible. It is important, however, that the faces determining the thickness, T, be as nearly parallel as possible. The deviation from parallelism of these faces should preferably be less than $\frac{1}{2{,}000{,}000}$ cm. In one specific case the output of a crystal-controlled oscillation generator was increased aproximately 250% by reducing the thickness variations of the crystal from .02 mm. to .002 mm., giving tangible proof that the faces under consideration should be as near optically parallel as they can be made.

The various phases of my invention, though seemingly disconnected, in reality contribute to the same end, i. e., the provision of frequency-controlling means for thermionic oscillation generators, so designed and constructed that maximum power may be obtained from the generator controlled thereby. The specific dimensions of the crystal are chosen for maximum output, the spacing between the crystal section and the upper electrode is maintained rigidly exact, and the

destructive sparking of prior art devices is prevented both by the low-pressure gas contained in the device and by the metallic plating previously described.

Among the advantages of the specific mounting illustrated may be mentioned the fact that the plates thereof do not deteriorate in use, and neither does their spacing vary appreciably. When in the oscillating state, a visible indicaton is given by a glow discharge between the electrodes, and the generated frequency is not marred by sparking.

Although I have illustrated and described certain preferred forms of my invention, the invention itself is not to be limited thereby, but is to be restricted only by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In combination, a container having a body of rarefied inert gas, and a plurality of non-oxidizable electrodes therein, a piezo-electric crystal interposed between said electrodes, having a ratio of L to W between 0.7 and 1.4, where W is one dimension of a face of the crystal in the direction of its optic axis and L is another dimension of said face, means whereby one of said electrodes is spaced from said crystal a distance which is a non-integral number of air-wave-lengths of the oscillation frequency of said crystal, and a metallic coating upon one or more of the faces of said crystal which are opposed to said electrodes.

2. In combination, a container having a body of rarefied inert gas, and a plurality of non-oxidizable electrodes therein, a piezo-electric crystal interposed between said electrodes and having a ratio of L to W between 0.7 and 1.4, where W is one dimension of a face of the crystal in the direction of its optic axis and L is another dimension of said face, and means whereby one of said electrodes is spaced from said crystal a distance which is a non-integral number of air-wave-lengths of the oscillation frequency of said crystal.

3. In combination, a container having a body of rarefied inert gas, and a plurality of non-oxidizable electrodes therein, and a piezo-electric crystal interposed between said electrodes and having a ratio of L to W between 0.7 and 1.4, where W is one dimension of a face of the crystal in the direction of its optic axis and L is another dimension of said face.

4. In an oscillation-controlling device, a plurality of substantially plane electrodes and means whereby one of said electrodes is supported from the other electrode at three points only.

5. In an oscillation-controlling device, a plurality of substantially plane electrodes, means whereby one of said electrodes is supported from the other electrode at three points only, a piezo-electric crystal interposed between said electrodes and means for preventing said crystal from being accidentally removed from its normal position.

6. In an oscillation-controlling device, a plurality of electrodes and a piezo-electric crystal section associated therewith, one of said electrodes being spaced away from the crystal a distance which is a non-integral number of air-wave-lengths of the oscillation frequency of said crystal.

7. In an oscillation-controlling device, a plurality of electrodes and a piezo-electric-crystal associated therewith, (said crystal) having a ratio of L to W between 0.7 and 0.9, where W is one dimension of a face of the crystal in the direction of its optic axis and L is another dimension of said face.

8. In an oscillation-controlling device, a plurality of electrodes and a piezo-electric-crystal section associated therewith, means for spacing one of said electrodes a definite distance from said crystal said distance being a non-integral number of air-wave-lengths of the oscillation frequency of said crystal and means for preventing destructive sparking from taking place across said crystal when the device is in operation.

9. As an article of manufacture, a piezo-electric-crystal section having a ratio of L to W between 0.7 and 0.9, where W is one dimension of a face of the crystal in the direction of its optic axis and L is another dimension of said face.

In testimony whereof, I have hereunto subscribed my name this 21st day of March, 1927.

RICHARD C. HITCHCOCK.