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W. G. CADY
METHOD OF MOUNTING PIEZO ELECTRIC RESONATORS
FOR THE EXCITATION OF VARIOUS OVERTONES
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1,782,117

Fig. 1

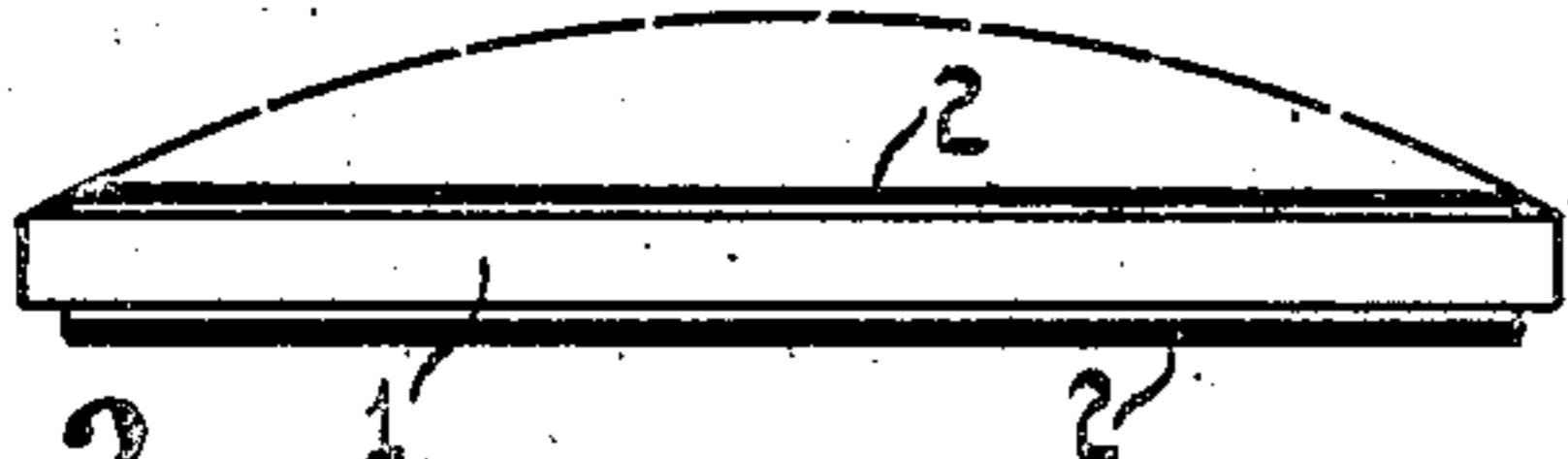


Fig. 2

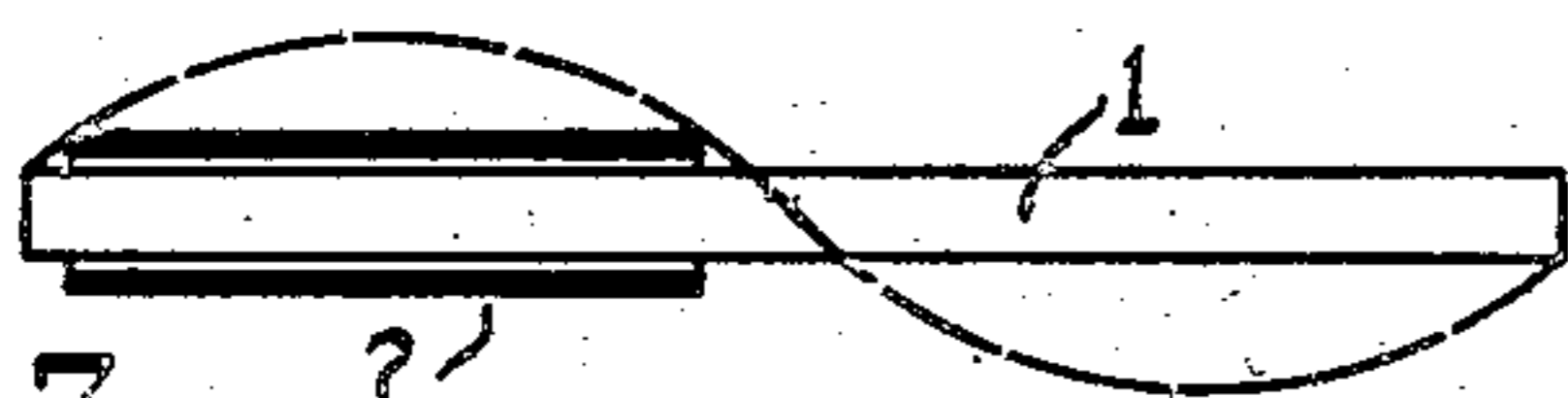


Fig. 3

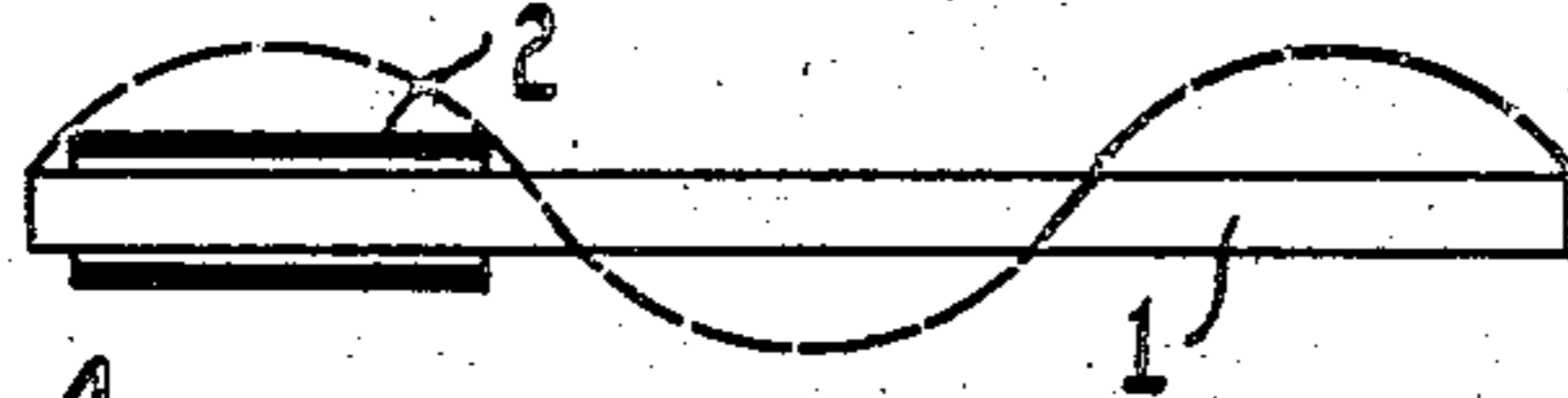


Fig. 4

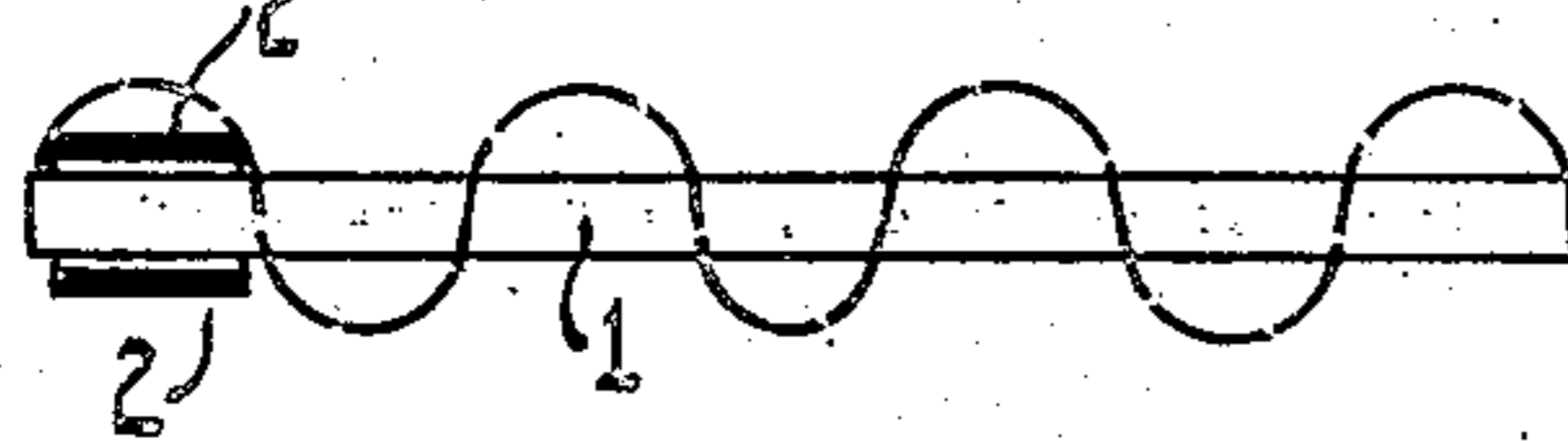


Fig. 7

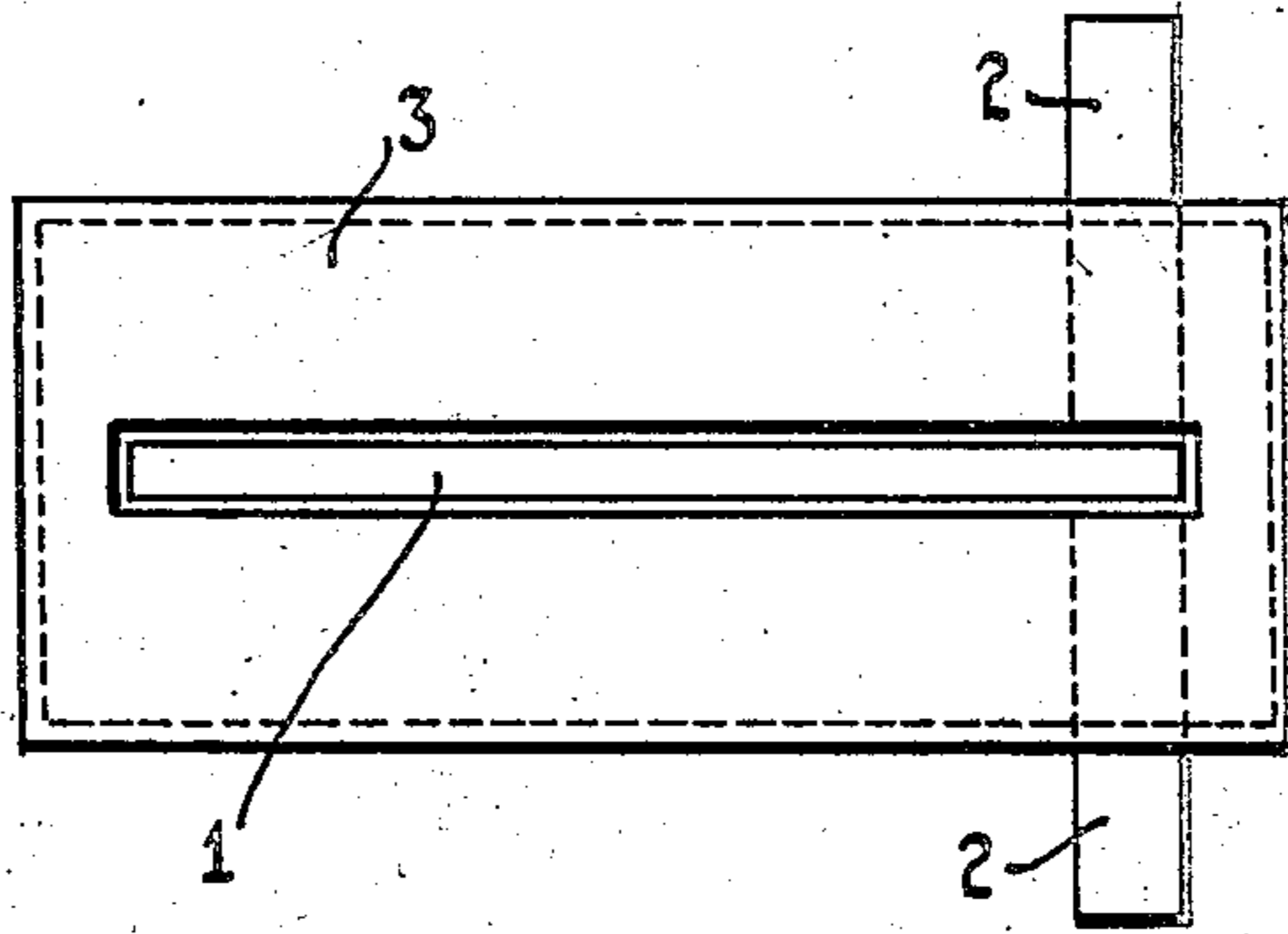


Fig. 5

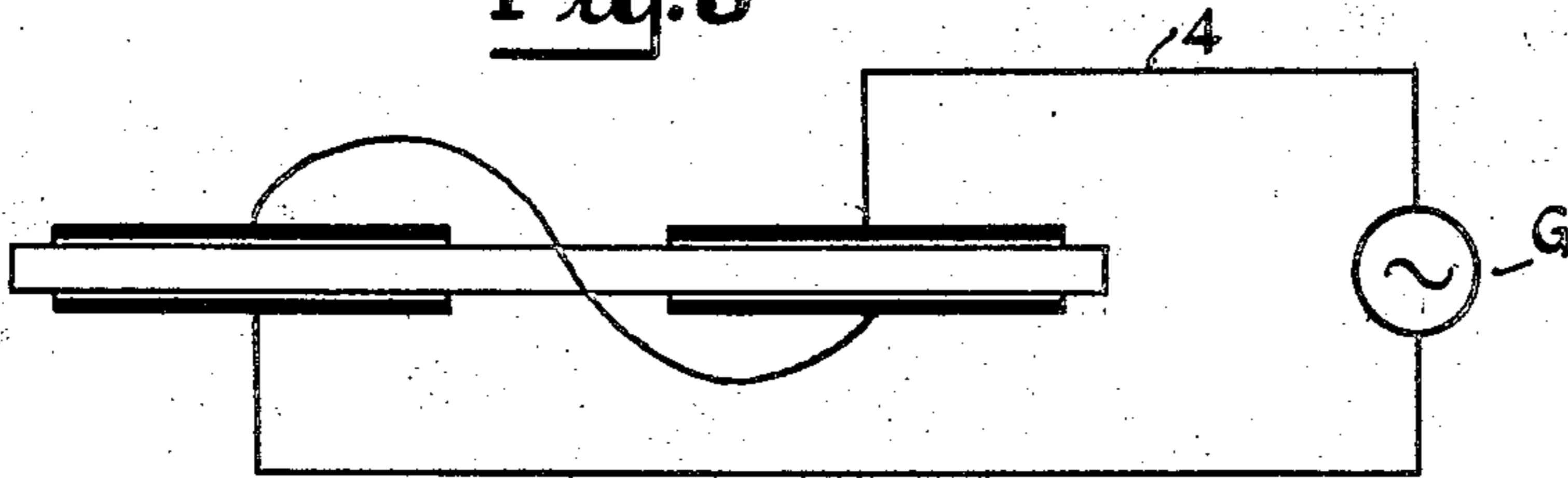
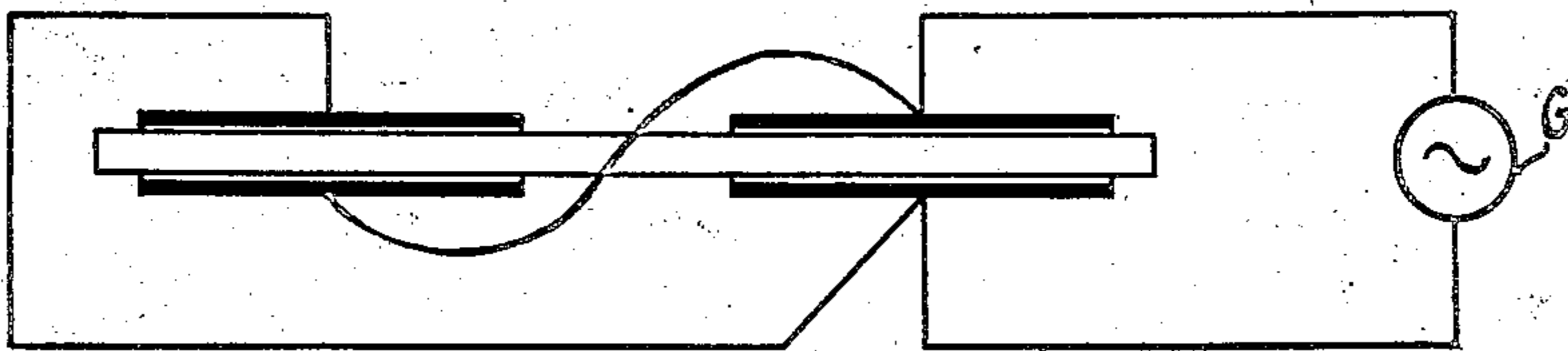


Fig. 6



INVENTOR
W. G. CADY
BY *Irving Adams*
ATTORNEY

UNITED STATES PATENT OFFICE

WALTER G. CADY, OF MIDDLETOWN, CONNECTICUT, ASSIGNOR TO RADIO CORPORATION OF AMERICA, A CORPORATION OF DELAWARE

METHOD OF MOUNTING PIEZO-ELECTRIC RESONATORS FOR THE EXCITATION OF VARIOUS OVERTONES

Application filed October 1, 1925. Serial No. 59,751.

In my Patent No. 1,450,246 I have described the piezo-electric resonator and explained the various applications thereof; and in my Patent No. 1,472,583 I have discussed the applications of piezo-electric bodies as a means of generating electric oscillations of constant frequencies, and also as frequency stabilizers. In general, I have in the said patents assumed that such piezo-electric bodies or resonators were vibrating at the fundamental or lowest frequency of the particular mode of vibration employed. I also refer as on page 4, lines 9 to 16 of my Patent No. 1,450,246, and page 2, lines 90 to 95, of my Patent 1,472,583 to the possibility of utilizing vibration frequencies other than the fundamental frequency.

As a rule a piezo-electric body, in common with other elastic solids, is capable of being stimulated into longitudinal vibration at various higher frequencies called overtones, which frequencies are approximately integral multiples of the fundamental frequency. In my paper in the Journal of the Optical Society, volumn 10, April 1925, entitled "Piezo-electric standards of high frequency," I have described on page 8 a method of mounting whereby various overtones may be excited.

The present invention relates to electro-mechanical resonators, or more specifically piezo-electric resonators, and the excitation of the piezo-electric body to vibrate at the fundamental frequency and also at its various overtones. It is to be understood that the vibrations herein referred to are longitudinal, and that the so-called transverse piezo-electric effect is employed as described in my foresaid Patent No. 1,472,583, page 1, lines 72 to 78. It is to be understood further that plates, rods, or other suitably shaped bodies including the entire crystal itself which is used as the piezo-electric body may be prepared according to methods which are well-known in the art. Reference is made to prior Patent No. 1,450,246 page 2, lines 39 to 55.

The present invention will be better understood from the following description taken in connection with the accompanying drawings

in which Fig. 1 is a top view of the crystal and its associated coatings arranged for excitation of the fundamental frequency of the crystal.

Figs. 2, 3, and 4 are similar views showing the arrangement of the coatings for the excitation of various overtones.

Fig. 5 shows a modification in which pairs of coatings are connected in series.

Fig. 6 is a view similar to Fig. 5 showing the coatings connected in parallel.

Fig. 7 is a top view showing the housing of the crystal.

Referring to the drawings, 1 is the piezo-electric body having a shape of a plate or rod. 2 is the metallic coatings which are associated with the crystal leaving a thin film of air between so that the crystal will be free to vibrate. The crystal lies in a pocket in the insulating base 3 for which a cover (not shown) may be provided. G is a source of alternating current of suitable frequency which is connected to the coatings 2 by means of the leads 4.

When a resonator (rod or plate of quartz, for example) is undergoing longitudinal vibration at its fundamental frequency there is at the center, if the ends are free to vibrate, a node of motion and a loop of compression; while at the ends are loops of motion, and nodes of compression. The compression is approximately sinusoidally distributed along the crystal as shown by the dotted lines in Figs. 1 to 4 inclusive.

Since both ends of the crystal plate are free, the length of the longitudinal wave is, for the fundamental frequency, approximately twice the length of the plate as shown in Fig. 1. The compression, and hence the piezo-electric effect is greatest at the center of the plate and sinks to zero at the ends. Hence the vibrations are excited most strongly when the conductive coatings are opposite the center portion of the plate. Nevertheless, the fundamental frequency can be excited sufficiently well for a good response, even when the coatings are near one end. Similarly, for the excitation of overtones, the vibrations, and hence the electrical reactions, of the plate, are most pronounced when the

coatings are placed opposite a portion of the plate where there is a loop of compression, as shown in Figs. 1 to 4. It is not important that the coatings should extend the full length of the half-wave of compression.

Fig. 2 represents the state of compression for the first overtone, which is very nearly twice the fundamental frequency. To excite this overtone, two coatings extending nearly half the length of the crystal may be used, as shown in this figure, or for stronger excitation two pairs of coatings may be employed; as in Fig. 5 connected in series, or as in Fig. 6 where the coatings are in parallel. For the second overtone, of approximately three times the fundamental frequency, one, two, or three pairs of coatings may be used. If one pair is used, it may be at either end, as in Fig. 3, or at the middle. Fig. 4 shows the compression curve and one pair of coatings for exciting the sixth overtone, and similarly for other overtones. One or more pairs of coatings may be used in each case.

I have found that with very short coatings at one end of the crystal, like those in Fig. 4 or in Fig. 7 it is possible to excite the fundamental and any of the overtones up to that corresponding to the length of the coatings, or even somewhat beyond, in a manner sufficiently strong for satisfactory operation of the crystal as a resonator. For each frequency the proper frequency of the source of electric oscillations must of course be supplied. The intensity of response is nearly the same for all these frequencies, and they all serve equally well for purposes of standardization of wave meters, etc. Thus a considerable number of standard frequencies may be obtained from one crystal. These frequencies will usually be the fundamental, together with overtone frequencies that are very nearly 2, 3 etc., times the fundamental frequency.

Inasmuch as any piezo-electric resonator can in general be used also for the generation or stabilization of electrical oscillations, when connected to a three-electrode vacuum tube or similar device which with the associated circuit possesses suitable characteristics, as set forth in my Patent No. 1,472,583, it follows that when a piezo-electric plate is mounted for the excitation of overtones, it may be used for the generation and stabilization of oscillations at overtone frequencies as well as at the fundamental frequency.

While the description and explanations herein contained refer more specifically to resonators prepared from piezo-electric crystals, nevertheless the essential points apply equally well to electro-mechanical vibrators of any form and material, so long as they are adapted to being stimulated into vibration at one or more overtone frequencies upon application of a suitable alternating electric field, and of reacting electrically upon the

circuit from which the said electric field is derived.

Having thus described my invention what I desire to claim and secure by Letters Patent of the United States is:

1. The method of stimulating a piezo-electric body to vibrate at a frequency higher than the fundamental frequency of said body which comprises, subjecting only a fractional portion of said body to an alternating electric field of suitable frequency.

2. The method of stimulating a piezo-electric body having a definite fundamental frequency of vibration to vibrate at a predetermined overtone which comprises impressing an alternating current field of suitable frequency upon opposite sides of a predetermined fractional portion only of said body.

3. The method of stimulating a piezo-electric body to vibrate at frequencies of approximately integral multiples of the fundamental which comprises, freely supporting said body to prevent damping of the vibrations of said body and subjecting only a fractional portion thereof to an alternating current field of substantially the desired frequency.

4. The method of exciting a piezo-electric body to vibrate longitudinally at overtones whereby the compression of the body varies sinusoidally from end to end, which comprises, subjecting the portions of said body where the loops of compression occur during the vibration of the body to an alternating current field of suitable frequency.

5. The method of stimulating a piezo-electric body into longitudinal vibration at an overtone to produce loops and nodes of compression which comprises, subjecting a portion of the body substantially equal to the distance between the said nodes of compression to an alternating current field of suitable frequency.

6. A piezo-electric resonator comprising, a piezo-electric body adapted to vibrate longitudinally to produce a plurality of loops and nodes of compression throughout the length thereof, and means including an alternating current of suitable frequency to stimulate the vibration of said body, said means being associated with said body substantially only at a loop of compression.

7. The method of stimulating a piezo-electric body to vibrate at a frequency higher than the fundamental frequency of said body which comprises, subjecting a fractional portion only of said body to an alternating electric field, said fractional portion being of a length which is substantially an integral subdivision of the length of said body.

8. A piezo-electric element adapted to vibrate at a plurality of overtones, comprising a piezo-electric crystal, a pair of conductive coatings on two opposite faces of said crystal, said coatings extending over a fractional part

of said faces, said fractional part being substantially of the order of the overtone it is desired to excite.

5 9. A piezo-electric element adapted to vibrate at a plurality of harmonic frequencies comprising a piezo-electric crystal, a pair of conductive coatings on two opposite faces of said crystal, said coatings extending over a fractional part of said faces, said fractional
10 part being substantially equal to

$$\frac{1}{n+1},$$

where n is the number of the overtone.

15 10. A piezo-electric resonator comprising, a piezo-electric body of predetermined length adapted to vibrate at overtones to produce a plurality of loops of compression throughout the length thereof, the number and length of
20 said loops of compression being determined by the overtone at which the body is vibrating, a plurality of pairs of coatings associated with said body, each coating being of a length substantially equal to one of said loops of
25 compression, and means to connect said pairs of coatings with an alternating current of suitable frequency.

WALTER G. CADY.

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