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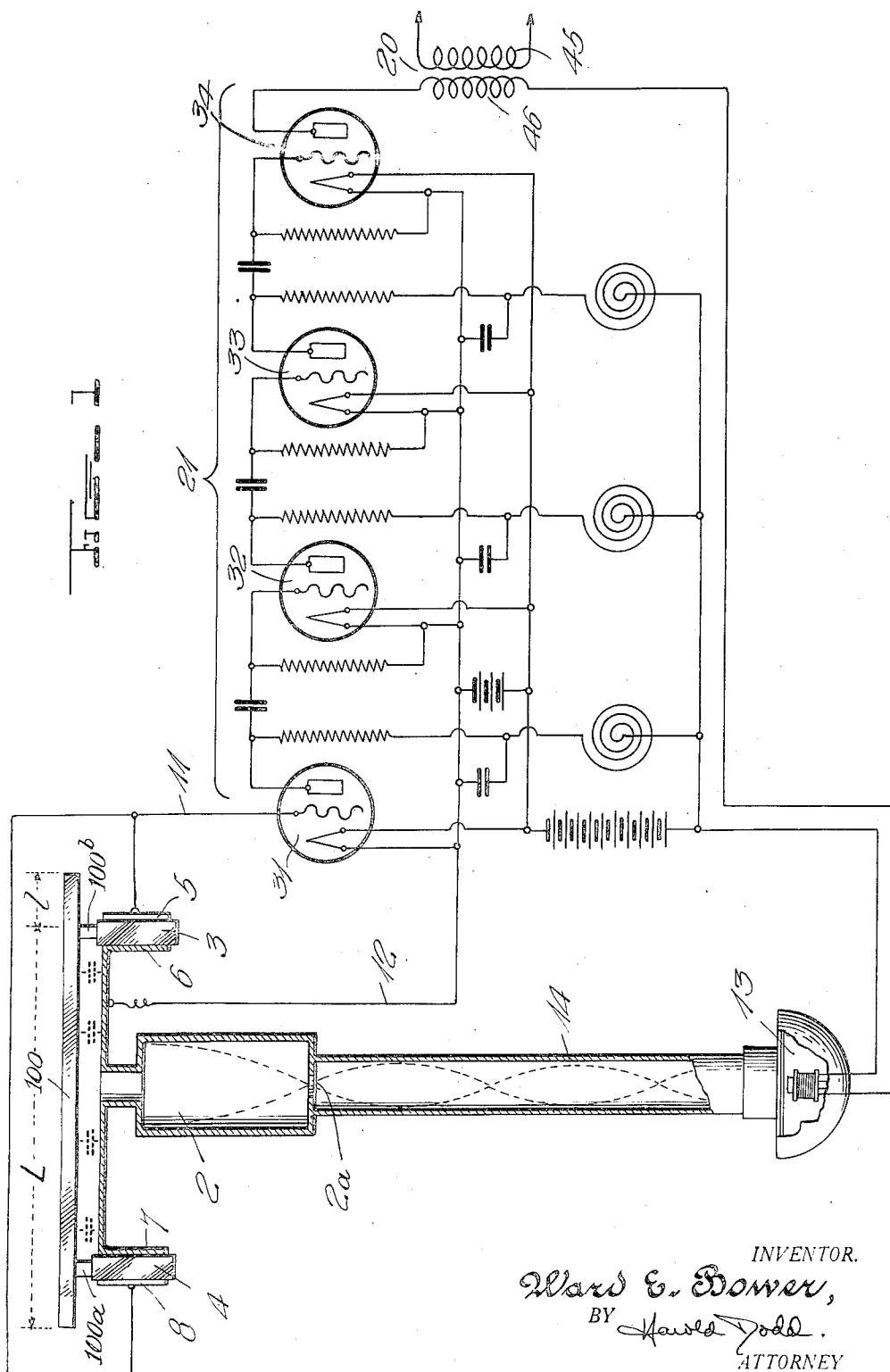
W. E. BOWER

1,921,501

OSCILLATION GENERATOR

Filed July 24, 1930

5 Sheets-Sheet 1



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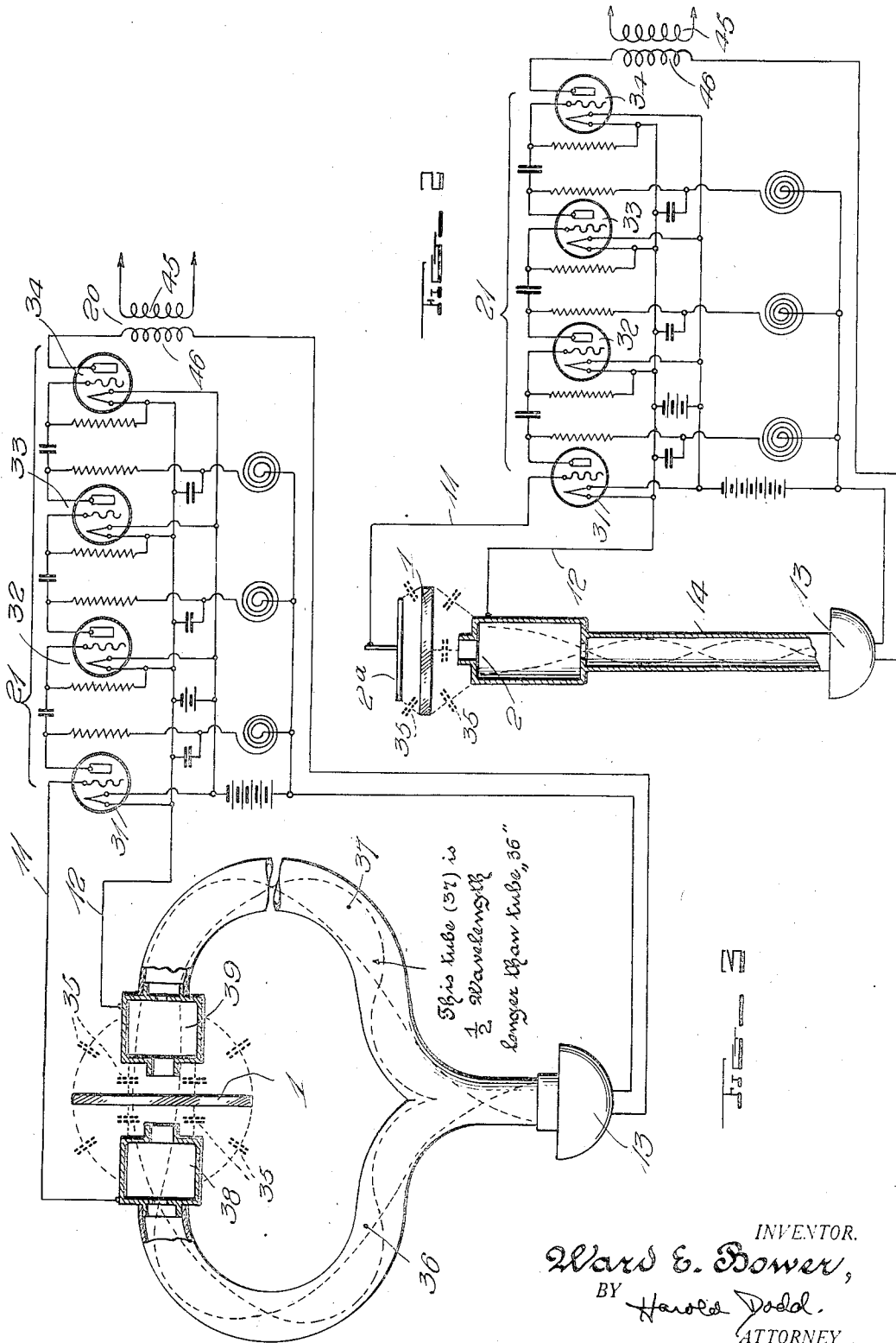
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5 Sheets-Sheet 2



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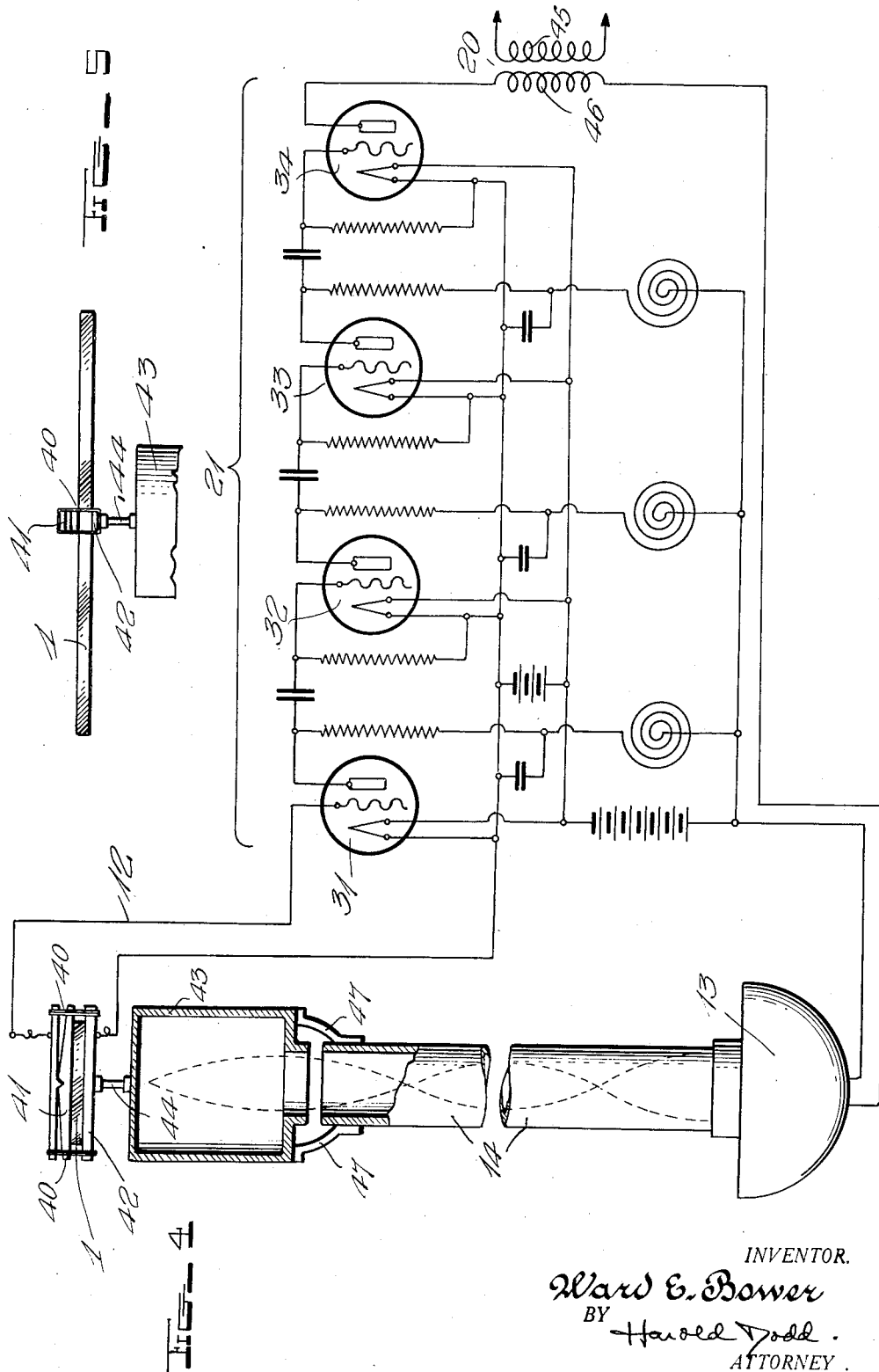
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5 Sheets-Sheet 3



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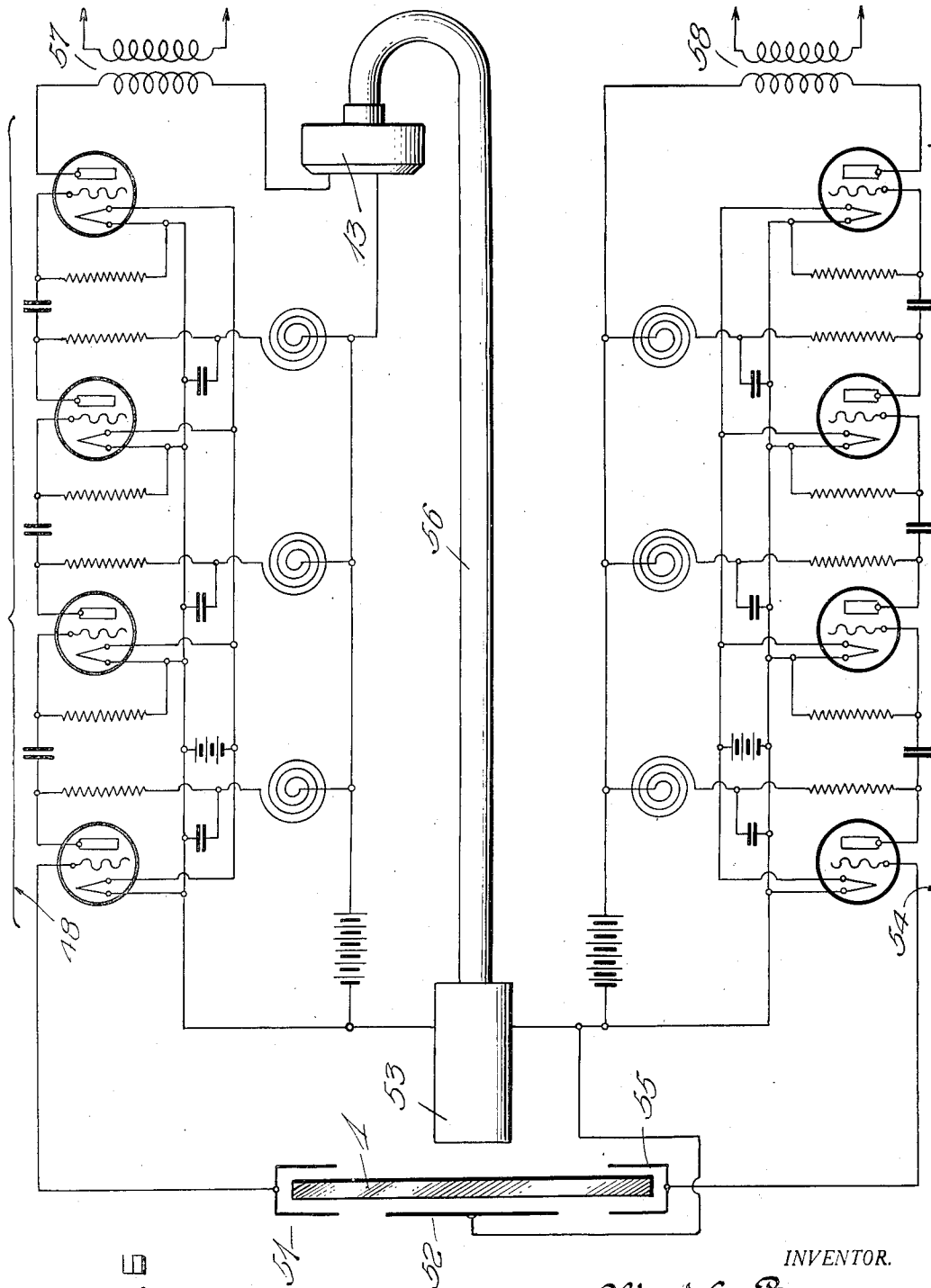
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5 Sheets-Sheet 4



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5 Sheets-Sheet 5

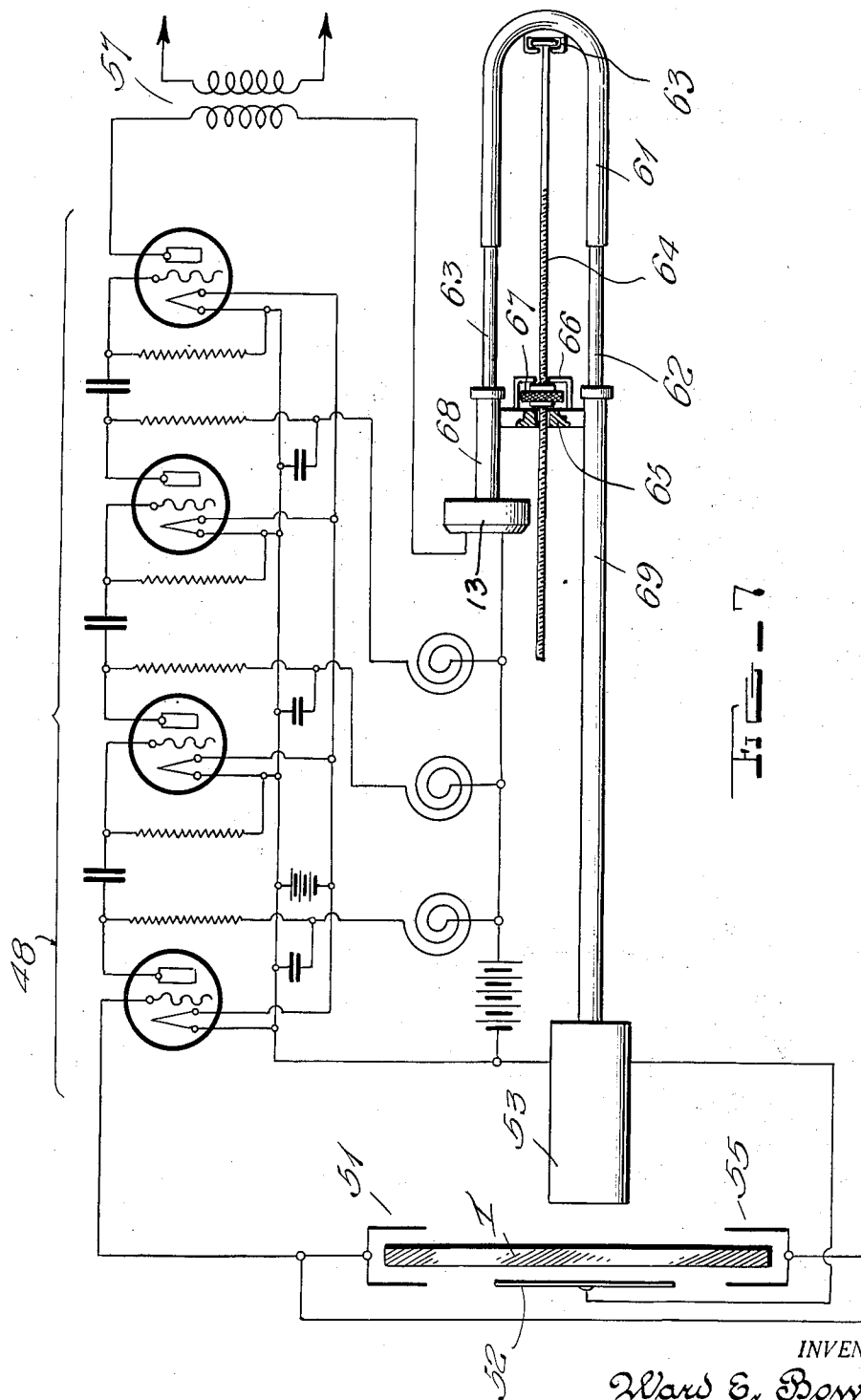


FIG. 7

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UNITED STATES PATENT OFFICE

1,921,501

OSCILLATION GENERATOR

Ward E. Bower, Washington, D. C.

Application July 24, 1930. Serial No. 470,447

18 Claims. (Cl. 250—36)

My invention relates broadly to electrical generators and more particularly to a precision type generator of electrical oscillations within the acoustic range.

One of the objects of my invention is to provide constant frequency oscillator including a mechanical vibratile element operating as a generator of oscillations and an acoustic feed back arrangement for maintaining the mechanical vibratile element in a condition of continuous oscillation.

Another object of my invention is to provide means for acoustically exciting a mechanically vibratile element in phase with the natural period thereof for sustaining constant frequency oscillations.

A further object of my invention is to provide an acoustic feed back system for synchronously exciting a mechanically vibratile element for generating oscillation of constant frequency.

A still further object of my invention is to provide means for subjecting a mechanically vibratile element with compressional and rarefactional forces on opposite faces thereof in synchronism with the period of the electrical oscillations generated by the mechanically vibratile element for sustaining oscillations at a predetermined frequency.

Other and further objects of my invention reside in the arrangement of acoustically actuated mechanically vibratile element arranged to control an oscillator system as set forth more fully in the specification hereinafter following by reference to the accompanying drawings in which:

Figure 1 diagrammatically illustrates the electrical generator and acoustic feed-back system of my invention; Fig. 2 shows a modified form of oscillator circuit embodying my invention; Fig. 3 shows a push-pull system of acoustic feed-back for sustaining oscillations generated by a mechanically vibratile element; Fig. 4 shows a modified form of mounting for a piezoelectric crystal element employed in the oscillator; Fig. 5 is a detail side view of the crystal mounting employed in Fig. 4; Fig. 6 shows a multiple generator system embodying my invention; and Fig. 7 shows a modified form of acoustic feed-back system for an audio frequency oscillator.

My invention is directed to a low frequency standard generator, having many improved features of importance over oscillation generators heretofore available. The oscillation generator system of my invention consists of an arrangement of an acoustical coupling between the controlling mechanical vibrating element and the

electrical system used to maintain the vibrations. By the device of my invention all electrical contacts are eliminated and the controlling element is left practically free to execute its natural oscillations affected only by its intrinsic mechanical properties and the surrounding atmospheric conditions. The apparatus has a degree of accuracy in the maintenance of a given frequency much greater than has heretofore been possible.

Referring to Fig. 1 of the drawings, reference character 100 designates a vibrating element which may be in the form of a bar, rod, disc, or cylinder supported in any convenient manner approximately symmetrically over the opening of an acoustical resonator indicated at 2. To this resonator are attached, as shown, two or more slabs of piezoelectric material represented at 3 and 4, which on being jarred by the vibrations of the master vibrator 100, develop a piezoelectric voltage on the electrodes, 5, 6, 7, and 8. These electrodes are connected as shown through leads 11 and 12 between the grid and cathode electrodes of electron tube 31. The voltage thus developed is amplified in any one of a number of well known methods of cascade amplification such as for example through the interconnected electron tube amplifier 21 having tubes 32, 33 and 34. The output of the amplifier is made to operate a loud speaker unit 13, or its equivalent, and this in turn actuates the air column 14, connected to the resonator 2, and so adjusted in length as to give the proper phase for the feed-back of energy to maintain the bar 100 in continuous vibration.

The master vibrator 100, may be of any material having suitable elastic constants such as metals, glass, or fused quartz. It may also be of any material showing piezoelectric effects, or of non-piezo-electric material veneered wholly or partially with piezoelectrical material. In the last two cases, the master vibrator must be so placed that the charges developed by its vibrations are so poled as to bring about a proper phase relation with the feed-back energy.

Vibrator 100 is mounted on felt or cork pads 100a and 100b at nodal points for the fundamental mode of vibration of bar 100, the projection of bar 100 on either side of the pads being approximately one fourth of the length L. Under some circumstances a well balanced bar 100 suspended lightly by silk threads at nodal lines will vibrate when the acoustical resonator or source is removed far from the bar, say 10 feet or more. The resonator 2 may be provided with a metering hole 2a determined as to size

by initial selection. If desired the metering aperture 2a may be made selectively adjustable.

The electromagnetic sound reproducer 13 establishes sound waves which are directed through the air column and vibrate the end of the chamber confining the air column as well as the means 100 adjacent the end of the air column. The means 100 and the portions of the chamber adjacent thereto in turn transmit these vibrations to the piezoelectric material represented at 3 and 4.

Referring to Figs. 2 and 3, the system may be applied as follows: I have shown the master vibrator 1, formed either from piezoelectric material, or of non-piezo-electric material veneered in whole or in part with piezoelectric material. The piezoelectric element may be hung by threads or supported in any other convenient manner as set forth in my copending application, Ser. No. 336,222 filed January 30, 1929, Patent No. 1,875,324, granted September 6, 1932. The charges developed when this vibrator is put in action by tapping or otherwise, are by electrostatic induction communicated to the electrodes formed by plate 2a and resonator 2 as indicated by the dotted line condensers 35. These charges are amplified and fed back through the loud speaker unit 13 and the acoustical system as described in connection with Fig. 1.

The method of operation shown in Fig. 3 differs from that in Fig. 2 by the provision of a "push-pull" acoustical feed-back. A double tube system shown at 36 and 37 of insulation material or metal tubes insulated from the resonators connects to the loud speaker 13 and delivers sound waves to the resonator chambers 38 and 39 respectively. The piezoelectric bar 1 or master vibrator is disposed between chambers 38 and 39 which serve as electrodes capacitively related to the faces of the piezoelectric crystal or master vibrator 1 as represented by dotted line condensers 35. The sound energy propagated through tube 37 is out of phase with the sound energy propagated through tube 36 by 180° phase when the sound reaches the resonance chambers 39 and 38 for tube 37 is one half wave length longer than tube 36. Therefore, the compressions and rarefactions occur alternately and in synchronism for applying push-pull forces to the crystal or master vibrator 1 and maintain the same in vibration.

Referring to Figs. 4 and 5, a method of applying the same principle is shown which differs from those described above, in that the master vibrator 1 which here must be of piezoelectric material, or of non-piezo-electric material veneered with piezoelectric material, is clamped symmetrically as shown between parts of a clamp 40, the two halves of the clamp 41 and 42 being insulated from each other and serving as collecting electrodes for the voltage developed by its vibrations. This voltage is then amplified and the energy necessary to sustain the vibrations fed back through a similar, though not identical, acoustical system to that described above. The resonance chamber is shown at 43 connected through link 44 with the lower electrode 42. The resonance chamber 43 is supported by members 47 adjacent the end of the air column 14.

In any of these methods of applying the principle, an electric current of a frequency determined by the master vibrator can be derived from the secondary winding 45 of the transformer 20 whose primary 46 is in the output of the last tube of the cascade amplifier. Connections may be

taken from the secondary winding 45 of transformer 20 to any desired point of application for the constant frequency energy. In the methods of use, shown in Figs. 1, 2, and 3, the points of support for the vibratile or master vibrator element 1 should be at or near the nodes of the mechanical vibrations which it is desired to utilize. When the method is applied as shown in Figs. 4 and 5, the point of support is the center of the vibrator 1.

Since, by the methods of use shown in Figs. 1, 2, and 3, the vibrating element is constrained in no way by electrodes or otherwise, except by its own intrinsic elastic properties and the atmospheric conditions existing in its vicinity, and since these latter can be made to be subject to very accurate control, this system affords a method of obtaining and maintaining a constant frequency within the range of acoustical frequencies of a precision much greater than has heretofore been attained.

A further advantage of my system is that it is possible when operated in any one of the methods shown in Figs. 1, 2, and 3, to have two (or more) master vibrators simultaneously operating from the same acoustical feed-back system, provided the master vibrators do not differ too much in frequency. Thus, it is possible to obtain from the output the sum and difference frequencies of the master vibrators, and hence the range of frequencies in which the method is applicable can be much extended.

In Fig. 6 I have schematically shown the essentials where 1 is a bar of metal treated or veneered with quartz or other piezo-electric material or genuine quartz bar may be employed and suspended at or near its nodes of free vibration in such a manner as to be free to oscillate in any of its nodes of vibration due to some external pulsing force loosely coupled thereto. Circuit 48 comprises an amplifier, the input circuit of which has the grid connected to electrode 51 on piezo-electric crystal 1 with connections from the opposite side of the input circuit to electrode 52 and to the resonance chamber 53 as shown.

Circuit 54 is an amplifier similar to amplifier 48. Electrode 55 on piezo-electric crystal or master vibrator 1 connects to the grid electrode of the first stage of amplification. The unit 13 is any of the well known loud speaker instrument and is here used to convert electrical energy into sound energy which is fed through the acoustical feed back tube 56 to supply energy to the acoustical resonator 53 in such a phase relation that if the crystal or master vibrator 1 or its equivalent is vibrating that said vibrations will be reinforced to such an extent that continuous oscillations are maintained at an amplitude proportional to the energy supplied by the acoustical system.

The bending of the master vibrator or piezo-electric generator 1 furnishes an electrostatic charge which fluctuates between minimum and maximum following a simple sine wave form. This piezoelectric voltage being collected by electrostatic coupling to the various electrodes causes an amplified grid voltage to operate in circuit 48 on the several tubes therein and in circuit 54 on the several tubes therein. The current through the output transformers 57 and 58 would normally be in exact phase relation. However, if in circuit 54 the electrode 55 which connects to the grid and the electrodes 52 and 53 which connect to the filament are reversed; viz, 55 terminating to the filament and 52 and 53 to the grid, then the out-

put of transformer 58 will be exactly 180° out of phase with the output of transformer 57.

In Fig. 7 I have shown a single acoustic feed-back system wherein the amplification system 48 is used alone in connection with the multiple electrodes of the piezo-electric crystal or master vibrator element 1. The circuits are so arranged that multiples or harmonics of the fundamental frequency of the crystal 1 may be selectively sustained by the acoustic feed-back of energy in selected timed relation.

The acoustic feed-back arrangement is modified by the addition of an adjustable yoke 61 which is telescopically slidable over tubular members 62 and 63, which slide into the ends of tubes 68 and 69 of the acoustic feed-back system. A bridge member 65 connects across tubes 68 and 69 and carries an extension 66 thereon through which the screw threaded member 64 passes. The screw threaded member 64 is engaged by the knurled thumb screw 67 for advancing the yoke 61 toward or away from tubular members 68 and 69. The end of adjusting screw 64 rotatably engages the socket 63 at the end of the yoke. In this manner the acoustic feed-back between electromagnetic sound reproducer 13 and resonance chamber 53 is varied. By adjustably tuning the acoustic feed-back system by selectively positioning the yoke 61 with respect to the tubular members 62 and 63, I am enabled to accurately adjust the acoustic system to the fundamental frequency of the mechanically vibratile element. While I have illustrated fixed air columns in the other figures of the drawings, it will be understood that the length of such air columns and resonators was originally determined by a tuning process. In order to increase the accuracy of the oscillator, I may introduce adjustable means for selectively fixing the length of the air column. The amplitude of the movement of the mechanically vibratile element is brought up to a maximum when the resonance chamber and air column are adjusted to the precise length corresponding to the fundamental frequency of the mechanically vibratile element.

I have found the acoustic feed-back principle as applied to a piezoelectric crystal controlled oscillator system highly efficient in its operation and accurate in its maintenance of constant frequency. While I have described my invention in certain of its preferred embodiments I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A generator of electrical oscillations comprising a piezoelectric element, means for supporting said piezoelectric crystal element for vibratory movement, an amplification system including an input circuit and an output circuit, connections between said piezoelectric element and said input circuit, an electromagnetic sound reproducer connected in said output circuit, and means for acoustically coupling said electromagnetic sound reproducer to said piezoelectric element for applying acoustic impulses against said piezoelectric crystal element in synchronism with the electrical impulses generated by said piezoelectric element for reinforcing the vibrations of

said piezoelectric crystal at constant frequency.

2. A generator of electrical oscillations comprising a mechanically vibratile element, means for suspending said element for vibratory movement, an electrical oscillatory circuit connected with said vibratile element, an electromagnetic sound reproducer energized by said circuit, and means for acoustically coupling said sound reproducer with said mechanically vibratile element for feeding back sound vibrations upon opposite sides of said mechanically vibratile element in cooperative phase relation for synchronously reinforcing and maintaining the oscillations in said circuit substantially constant.

3. A generator of electrical oscillations comprising a mechanically vibratile element, means for suspending said mechanically vibratile element for vibratory movement, an electron tube amplification system having an input circuit and an output circuit, connections between said input circuit and said mechanically vibratile element for sustaining electrical oscillations at a frequency determined by the characteristics of said mechanically vibratile element, a sound reproducer connected with said output circuit, and means acoustically coupling said sound reproducer with opposite sides of said mechanically vibratile element for subjecting said mechanically vibratile element to sound vibrations in cooperative phase relation at each side thereof in step with the mechanical vibrations of said mechanically vibratile element for maintaining the oscillations in said amplification system substantially constant.

4. An oscillation generator comprising a mechanically vibratile element, an amplification system having an input circuit and an output circuit, connections between said mechanically vibratile element and said input circuit, a tone frequency electromagnetic sound reproducer connected in said output circuit, and means acoustically coupling said sound reproducer with opposite sides of said mechanically vibratile element for alternately subjecting said mechanically vibratile element to compressional and rarefactional forces in synchronism with the oscillation characteristics of said mechanically vibratile element, whereby oscillations of constant frequency are sustained through said amplification system.

5. An oscillation generator comprising an electron tube system having an input circuit, a work circuit, an electromagnetic sound reproducer connected in said work circuit, a piezoelectric crystal element connected in said input circuit for generating electrical oscillations, and means acoustically coupling said electromagnetic sound reproducer with opposite sides of said piezoelectric crystal element in cooperative phase relation for reinforcing the vibratory movement of said piezoelectric crystal element, whereby oscillations of constant frequency are sustained in said work circuit.

6. An oscillation generator comprising a mechanically vibratile element, an electrical circuit including said element, a sound reproducer connected in said electrical circuit, a work circuit connected to said electrical circuit, and means acoustically coupling said sound reproducer with opposite sides of said mechanically vibratile element for subjecting said mechanically vibratile element to the effects of sound vibrations in different phase relations for sustaining oscillations in said work circuit at substantially constant frequency.

7. An oscillation generator comprising a mechanically vibratile element, a pair of resonance chambers disposed on opposite sides of said mechanically vibratile element, a sound reproducer
5 connected with said resonance chambers for supplying sound vibrations to said resonance chambers in different phase relations, a circuit coupling said mechanically vibratile element with
10 said electromagnetic sound reproducer for effecting a continuous feed back of electrical and acoustic energy, and a work circuit connected with said aforesaid circuit for sustaining oscillations at substantially constant frequency.
8. An oscillation generator comprising a piezo
15 electric crystal element, means for suspending said piezoelectric crystal element for vibratory movement, a circuit connected with said element for sustaining oscillations generated by said
20 piezoelectric crystal element, an electromagnetic sound reproducer connected with said circuit for reproducing sound vibrations corresponding to the oscillations generated by said piezoelectric
25 crystal element and means for applying acoustic vibrations developed by said sound reproducer to opposite sides of said piezoelectric crystal element in cooperative phase relation for sustaining
30 oscillations in said circuit at constant frequency.
9. An oscillation generator comprising a piezo
35 electric crystal element, a circuit for sustaining oscillations generated by said piezo electric crystal element, and means for regeneratively applying
40 acoustic vibrations to opposite sides of said piezoelectric crystal element in different phase relations for sustaining oscillations at substantially
45 constant frequency.
10. A piezoelectric crystal apparatus including
45 a piezoelectric crystal element, electrodes capacitatively related to said piezoelectric crystal element, each of said electrodes comprising
50 substantially hollow resonance chambers, and means for imparting sound vibrations through said resonance chambers against said piezoelectric
55 crystal element.
11. Piezoelectric crystal apparatus comprising
55 a piezoelectric crystal element, and a pair of capacitatively related electrodes adjacent the opposite surfaces of said piezoelectric crystal element, each of said electrodes comprising substantially
60 hollow resonance chambers for impressing acoustic vibrations against the surfaces of said
65 piezoelectric crystal element.
12. Piezoelectric crystal apparatus comprising
65 a multiplicity of piezoelectric crystal elements, a resonance chamber, means extending from said
70 resonance chamber and supporting said piezoelectric crystal elements and establishing electrical connection with one surface of each of said
75 piezoelectric crystal elements, means establishing electrical connection with the opposite surfaces of said piezoelectric crystal elements, a sound generator controlled by said piezoelectric
80 crystal elements, and means for introducing sound vibrations from said sound generator through said resonance chamber for simultaneously
85 subjecting said piezoelectric crystal elements to acoustic vibrations proportional to the natural period of said piezoelectric crystal elements and in synchronism with the operation
90 thereof.
13. Piezoelectric crystal apparatus comprising
95 a multiplicity of piezoelectric crystal elements, a resonance chamber constituting one electrode for
100 said crystal elements, means for supporting said piezoelectric crystal elements with respect to said resonance chamber, separate mechanical means
105 interconnecting said piezoelectric crystal elements adjacent said supporting means, electrodes for establishing electrical connection with the
110 surfaces of said piezoelectric crystal elements, a sound generator controlled by said piezoelectric crystal elements and a sound conveying tube
115 acoustically connected with said sound generator for introducing sound vibrations through said
120 resonance chamber in proportion to the natural period of said piezoelectric crystal elements.
14. An oscillation generator comprising a mechanically vibratile element, a pair of independent
125 amplifier circuits, a separate work circuit connected with each of said amplifier circuits, an electromagnetic sound reproducer connected to the output circuit of one of said amplifier
130 circuits, individual connections between said mechanically vibratile element and the input circuits of said amplifier circuits, and an acoustic coupling between said sound reproducer and said
135 mechanically vibratile element, whereby oscillations are generated in one work circuit in outer phase relation to the oscillations generated in the other work circuit.
15. In an oscillation generator, a piezoelectric
140 crystal element, a pair of independent amplifier circuits, means connecting the input circuits of each of said amplifier circuits with said piezoelectric crystal element in out of phase relation, separate
145 work circuits connected with each of said amplifier circuits, a loud speaker reproducer connected to the output circuit of one of said amplifier circuits, and means acoustically coupling
150 said loud speaker reproducer with said piezoelectric crystal element for regeneratively sustaining oscillations and impressing the oscillations thus sustained upon said separate work circuits at substantially constant frequency in out
155 of phase relation.
16. An oscillation generator comprising a piezo-
160 electric crystal element adapted to generate a fundamental frequency and harmonics and multiples thereof, an amplification circuit electrodes disposed adjacent said piezoelectric crystal element and connected to the input of said amplification
165 circuit, a work circuit connected with said amplification circuit, an electromagnetic sound reproducer connected in the output circuit of said amplification circuit, and means for acoustically coupling
170 said electromagnetic sound reproducer with said piezoelectric crystal element for subjecting said piezoelectric crystal element to sound vibrations in synchronism with the self-vibration
175 of said piezoelectric crystal element and sustaining oscillations of constant frequency in said work circuit.
17. An oscillation generator comprising a piezo-
180 electric crystal element, means for mounting said piezo electric crystal element for vibration, an amplification circuit, a work circuit connected therewith, an electromagnetic sound reproducer connected with the output circuit of said amplification
185 circuit, electrodes disposed adjacent said piezoelectric crystal element and connected with the input circuit of said amplification circuit, one of said electrodes being constituted by a substantially
190 hollow resonance chamber, and adjustable means acoustically coupling said electromagnetic sound reproducer with said resonance chamber for impressing sound vibrations upon said
195 piezoelectric crystal element in step with the natural vibration thereof and reinforcing the operation of said crystal element for establishing

substantially constant frequency oscillations in said work circuit.

18, An oscillation generator comprising a piezo electric crystal element, means for mounting said piezoelectric crystal element for vibratory movement, sets of electrodes adjacent opposite ends and adjacent opposite faces of said piezoelectric crystal element, one of said electrodes adjacent one of the faces of said piezoelectric crystal element constituting a substantially hollow resonance chamber, an electron tube system having an input circuit connected with said electrodes

for sustaining oscillations under control of said piezoelectric crystal element, a sound generating device connected in the output of said electron tube system, means acoustically coupling said sound generating device with the resonance chamber electrode adjacent said piezo electric crystal element for directing sound vibrations upon said piezoelectric crystal and reinforcing the movement thereof, and a work circuit connected with said electron tube system for utilizing the oscillations thus generated.

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