

Nov. 23, 1926.

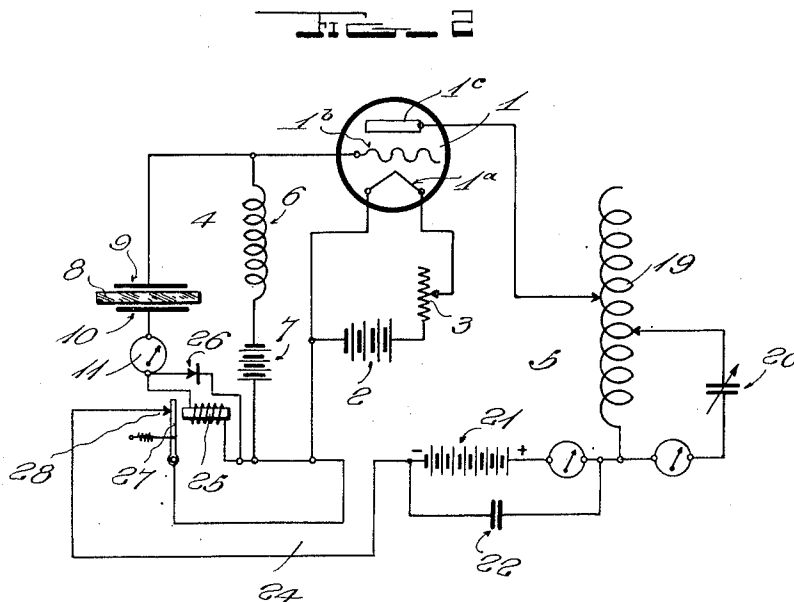
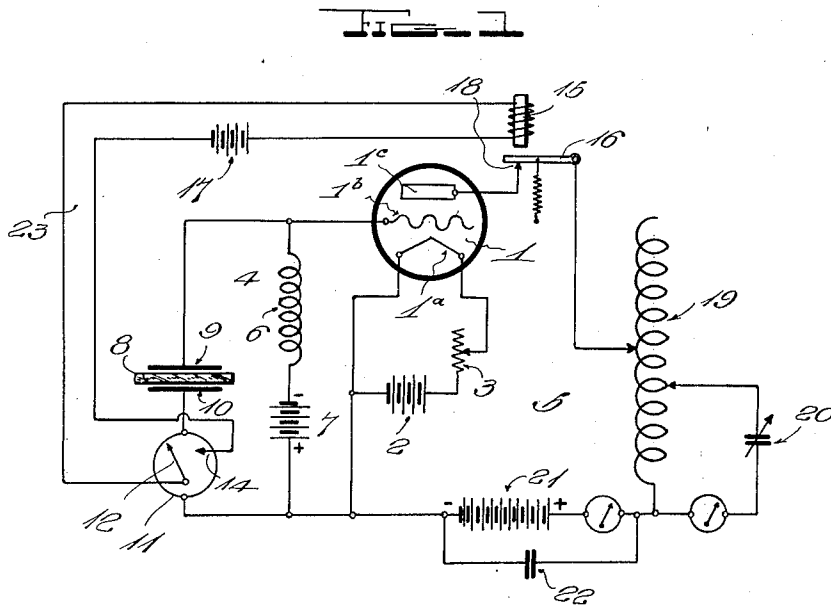
1,608,048

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PIEZO ELECTRIC CRYSTAL CONTROL SYSTEM

Filed Jan. 23, 1926

2 Sheets-Sheet 1



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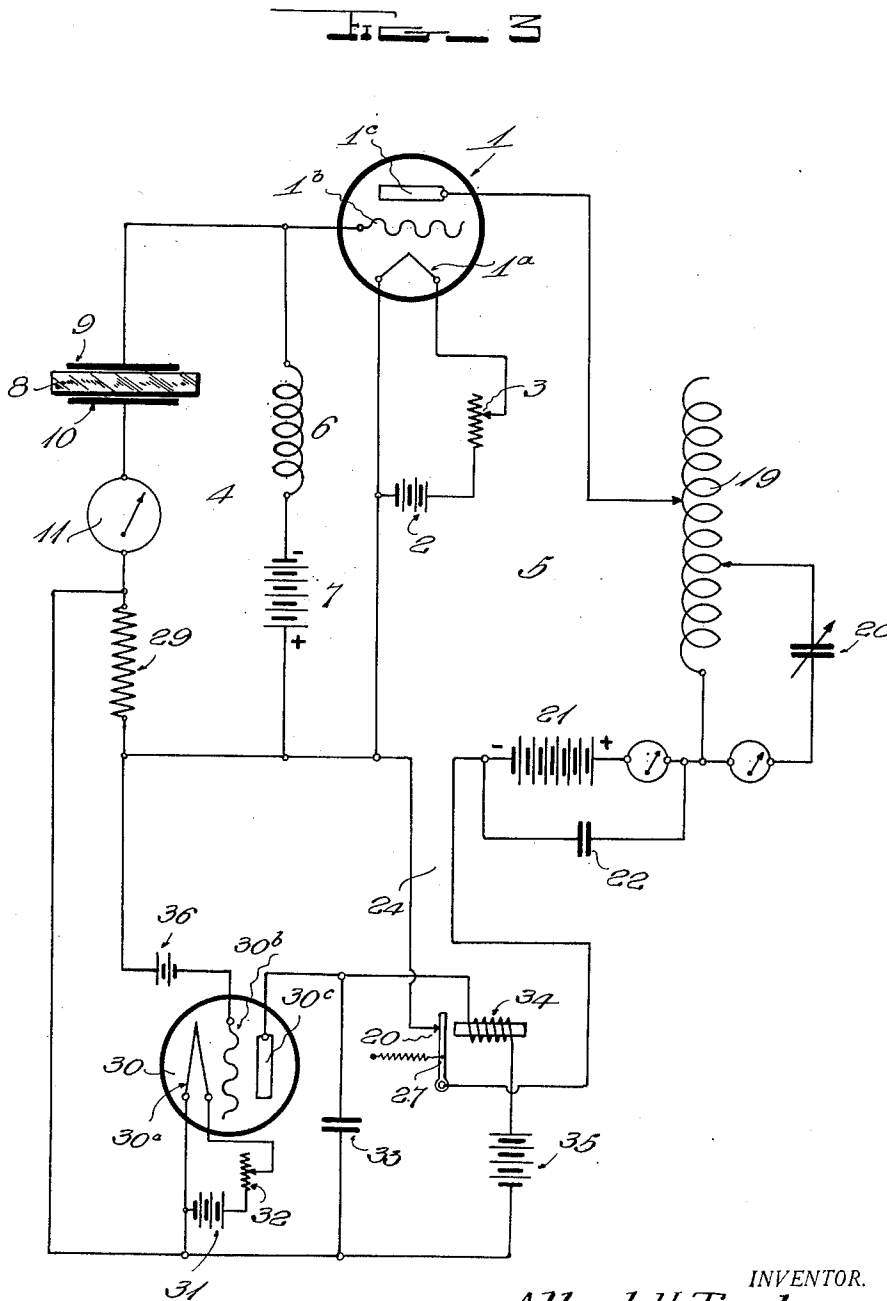
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PIEZO ELECTRIC CRYSTAL CONTROL SYSTEM

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE.

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PIEZO-ELECTRIC-CRYSTAL CONTROL SYSTEM.

Application filed January 23, 1926. Serial No. 83,408.

My invention relates broadly to piezo electric crystal control circuits, and more particularly to a protective circuit arrangement for preventing the fracture or break down of piezo electric crystals under conditions of over-loading.

One of the objects of my invention is to provide a piezo electric crystal control system with means for preventing the fracture or break down of piezo electric crystals under conditions of excessive currents in the circuits of an electron tube oscillating system which the piezo electric crystal is arranged to control.

Another object of my invention is to provide an electron tube piezo electric crystal controlled oscillator system where the piezo electric crystal is protected against excessive radio frequency currents by a current limit relay circuit arranged to break the oscillator circuit upon increase of the radio frequency current beyond a safe value.

Still another object of my invention is to provide an automatic protective system for piezo electric crystals by which rise in current through the piezo electric crystal operates to break the plate circuit for preventing increase of the current through the piezo electric crystal to a point where the crystal may be strained or ultimately destroyed.

My invention will be more clearly understood by reference to the accompanying drawings, wherein:

Figure 1 shows diagrammatically an electron tube oscillator with a circuit for protecting the piezo electric crystal control in accordance with the principles of my invention; Fig. 2 illustrates a modified circuit arrangement for the protection of the piezo electric crystal circuit which connects with the electron tube oscillator; and Fig. 3 illustrates still another modified arrangement of piezo electric crystal controlled and oscillator circuit having an electron tube protective system operating upon increase in radio frequency current beyond a predetermined value for breaking the electron tube oscillator circuit.

In the operation of piezo electric crystal control circuits for radio transmitters conditions have arisen in which the piezo electric crystal has been fractured or broken destroying the operation of the crystal. I have observed that under continuous opera-

tion the crystal becomes hot, due, among other things, to the rapid mechanical vibration of the crystal and excessive current passing through the crystal.

Ordinarily, when operating a $7\frac{1}{2}$ watt tube with quartz crystal control, the only method the operator has of judging the condition of the crystal is to observe carefully for brushing and look at the crystal from time to time to determine whether flaws are developing, and test the temperature to see if it is too hot. These methods are all unsatisfactory. Brushing can be very damaging long before it can be seen, and over-heating under this condition, takes place so rapidly that the crystal would be destroyed before the over-heated condition could be discovered. Attempt has been made in radio transmitter operation to so adjust the number of turns in the inductance in the plate circuit of the piezo electric crystal controlled oscillator that the energy in the plate circuit, and therefore the output radio frequency energy, is held down. In spite of this precaution, however, piezo electric crystals have been shattered and broken into pieces in oscillator circuits due to excessive rise in current in the piezo electric crystal control circuit. Theoretical considerations indicate that the thing which determines the condition of the crystal more than anything else, is the amount of radio frequency current supplied to the grid of the tube which is obliged to pass through the crystal or rather through that capacity determined by the top and bottom plates of the crystal with the crystal itself as an intervening dielectric. By placing a radio frequency milliammeter in the grid circuit of the piezo electric crystal controlled oscillator either above or below the piezo electric crystal, the rise in current through the piezo electric crystal may be observed. A position next to the grid electrode of the oscillator, that is, above the piezo electric crystal in the input circuit of the oscillator is preferable if the meter can be so mounted as to offer little capacity between the case of the meter and the earth, otherwise it is better to insulate the lower crystal contact plate and place the meter in the lower position. It has now been definitely determined that for normal crystal operation, the permissible grid current at radio frequencies which in a way passes through the crystal, has a very defi-

nite upper limit beyond which heating will rapidly develop and the crystal structure is liable to be flawed, fractured, or otherwise damaged. This permissible radio frequency current through the crystal is directly proportional to the area of the crystal and in general up to 4000 kcs., increases with the frequency. The fallacy of the arrangement of protecting the crystal by increasing the plate turns and settings until the output falls off will be readily understood. Investigations have shown that when the plate turns are increased (thereby reducing power input and power output) the radio frequency grid currents increase, thereby subjecting the crystal actually to a greater strain with a light load, than it would have had with a heavier one.

I have determined a number of working values for crystals having a six square cm. of area and operating under normal conditions without over-heating; these values range from 15 radio frequency milliamperes at 500 kcs. to 150 radio frequency milliamperes at 6000 kcs. The value of milliamperes of direct current in the plate circuit of the oscillator is relatively unimportant. The latter tells the operator nothing whatever about the crystal although it does give warning when the tube itself is going to overheat, but at the present time crystals are far more valuable than tubes; at least $7\frac{1}{2}$ watt tubes. The circuit is started out on a low voltage, generally 220 volts on the plate, and the plate turns are adjusted downward until a reasonably good circuit adjustment is obtained with the radio frequency grid mills at a low value. Then the voltage is raised until the radio frequency grid mills reach the maximum safe limit. This is practically the reverse of the former method of adjusting crystal circuits, because instead of starting out with a large number of plate turns, thus holding back the plate (D. C.) milliamperes, the plate turns are started low, holding back the radio frequency grid milliamperes. The use of the grid milliammeter permits observations to be made with safety with 50 watt tubes, whereas prior to this, it has been thought that it was not entirely safe to try to operate a 50 watt tube with crystal control unless intervening amplifiers were employed. A great many crystals were fractured in the attempt to accomplish direct operation of the crystal in the input circuit of a high frequency tube. With my circuit arrangement, however, it is now entirely possible to operate 50 watt tubes not always to full output, but to much higher power, than can be expected with a $7\frac{1}{2}$ watt tube provided the circuit is adjusted with reference to the grid radio frequency milliammeter and the output radio frequency meter with little or no reference to the plate current. I have found that the

radio frequency grid milliamperes is a direct function of the grid to plate capacity, and that a tube that has a high amplification constant and at the same time a relatively low grid to plate capacity, is the ideal tube for direct operation with a crystal. The radio frequency grid milliammeter has, therefore, become an important adjunct in a piezo electric crystal control circuit.

I make use of the operation of a radio frequency grid milliammeter for automatically opening the plate circuit of an electron tube oscillator when the grid current rises above a predetermined limit. An automatic control circuit is also provided in series with the piezo electric crystal for operation upon rise in grid current beyond a given limit and thereby opening the plate circuit of the oscillator for maintaining the current through the piezo electric crystal below a safe limit. I may also utilize the increase in the drop across a resistance in series with the piezo electric crystal for controlling the operation of an electron tube circuit and actuating a current limit relay in the plate circuit thereof when the current through the piezo electric crystal tends to rise beyond a safe limit.

Referring to the drawings in more detail, reference character 1 indicates an electron tube having filament, grid and plate electrodes 1^a , 1^b and 1^c . The filament or cathode 1^a is heated from source 2 under control of rheostat 3. An input circuit 4 is provided connected across the grid and filament electrodes, and an output circuit 5 is provided connected across the plate and filament electrodes. The input circuit 4 includes a choke coil 6 and a source of potential 7 connected across the input circuit in such manner that the piezo electric crystal 8 may be operated in the input circuit 4 under substantially no load. The contact plates 9 and 10 are provided between which the piezo electric crystal 8 is mounted. The radio frequency milliammeter 11 is connected in series with the piezo electric crystal 8 as shown. The indicator 12 may be entirely insulated from the mechanism of the milliammeter 11 and arranged to close an electrical circuit with contact 14 set at a point along the scale of the milliammeter at which the current may increase to a predetermined limit below a value that may be destructive to the piezo electric crystal 8. A relay having a spring tensioned armature 16 and a contact member 18 is provided in the output circuit 5 of the electron tube oscillator. The relay includes an electromagnetic winding 15 which is connected in a circuit 23 including the indicator arm 12, adjustable contact 14 and battery 17. The output circuit 5 of the electron tube oscillator includes inductance 19, variable capacity 20, high potential source 21, shunting condenser 22 and the

necessary meters. The piezo electric crystal functions to control the oscillations developed in the electron tube oscillator system and will continue to maintain the oscillations therein at constant frequency so long as the current through said piezo electric crystal remains below a predetermined limit and a safe value. Upon rise of current through piezo electric crystal 8 the indicator arm 12 completes connection with contact 14 energizing the relay winding 15 and opens the plate circuit of the oscillator, thus automatically protecting the piezo electric crystal against excessive current.

In Fig. 2 I have illustrated a rectifier 26 in circuit with the piezo electric crystal 8 whereby the direct current component proportional to the radio frequency current through piezo electric crystal 8 energizes winding 25 with which is associated the spring tensioned armature 27 which normally connects with the back contact 28. The plate circuit of the electron tube oscillator extends along the connections represented at 24 and is completed through armature 27 and contact 28. Upon excessive rise of current through the piezo electric crystal 8, the plate circuit of the oscillator is thereby automatically interrupted and the piezo electric crystal protected against the destructive effects of excessive currents.

As represented in Fig. 3 a resistance 29 may be connected in series with the piezo electric crystal 8 and an electron tube 30 having filament, grid and plate electrodes 30^a, 30^b and 30^c provided and arranged to be controlled by the drop across resistance 29. The cathode 30^a is heated from battery system 31 under control of rheostat 32. The output circuit of electron tube 30 includes high potential source 35 and relay winding 34 shunted by condenser 33. A spring tensioned armature 27 is arranged to be actuated by relay winding 34 with a contact 28 normally closed by the spring tensioned armature 27 for completing the plate circuit of the oscillator in a manner similar to that represented in Fig. 2. The operating characteristics of tube 30 may be so controlled by a proper value of grid potential represented at 36 that upon rise in current through piezo electric crystal 8, the relay winding 34 operates to open the plate circuit of the oscillator.

While I have illustrated several circuit arrangements for the protection of piezo electric crystals against the destructive effects of excessive currents, it will be understood that the methods shown are for illustrative purposes only and that the principles of my invention may be embodied in various ways and that no limitations upon the invention are intended other than those imposed by the scope of the appended claims.

What I claim and desire to secure by Let-

ters Patent of the United States is as follows:

1. A piezo electric crystal control system comprising in combination an electron tube oscillator, a piezo electric crystal for controlling oscillations generated by said electron tube oscillator, and means for opening the circuit of said electron tube oscillator upon increase in current through said piezo electric crystal beyond a predetermined limit.

2. A piezo electric crystal control system comprising in combination an electron tube oscillator, a piezo electric crystal for controlling the operation of said electron tube oscillator, and means connected in series with said piezo electric crystal for opening the circuit of said electron tube oscillator when the current through said piezo electric crystal rises beyond a predetermined limit.

3. A piezo electric crystal control system comprising in combination an electron tube oscillator, input and output circuits connected with said oscillator, a piezo electric crystal arranged in said input circuit for controlling the frequency of oscillations developed by said electron tube oscillator, and means connected in series with said piezo electric crystal in said input circuit for breaking said output circuit for preventing injury to said piezo electric crystal due to rise of current in said input circuit beyond a predetermined limit.

4. A piezo electric crystal control system comprising in combination with an electron tube oscillator having input and output circuits, a piezo electric crystal connected in said input circuit, a relay interposed in said output circuit, and means connected in series with said piezo electric crystal in said input circuit for actuating the relay in said output circuit when the current through said piezo electric crystal exceeds a predetermined value.

5. A piezo electric crystal control circuit comprising in combination an electron tube oscillator, input and output circuits connected with said oscillator, a piezo electric crystal arranged in said input circuit, a relay interposed in said output circuit including a spring tensioned armature and a contact member, and a winding for said relay arranged to be energized upon increase in current through said piezo electric crystal for moving said armature away from said contact and breaking said output circuit for preventing rise of current through said piezo electric crystal beyond a predetermined value.

6. In an electron tube oscillator system, a space current discharge device including an evacuated envelope containing a plurality of electrodes, circuits interconnecting said electrodes, a piezo electric device for controlling the operation of said circuits

and a current limit relay actuated by excessive current through said piezo electric device for interrupting the operation of said space current discharge device.

- 5 7. In combination, a space current discharge device comprising an evacuated envelope containing a plurality of electrodes, a piezo electric device for controlling the operation of said space current discharge device and automatic means responsive to
10 increase in current through said piezo electric device for rendering said space discharge device inoperative.

8. In combination, a space current discharge device comprising an evacuated envelope, a plurality of electrodes, a piezo electric device for normally controlling the operation of said space current discharge device, and magnetic means responsive to
20 an increase in current through said piezo electric device for rendering said space discharge device inoperative.

9. In combination, a space current discharge device comprising an evacuated envelope, a plurality of electrodes, a piezo electric device for normally controlling the operation of said space current discharge device, and a current limit electromagnetic relay device responsive to increases in current through said piezo electric device for rendering said space discharge device inoperative.
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10. An electron discharge device comprising an envelope, cathode, anode and control

electrodes therein, circuits interconnecting said electrodes, a piezo electric device in one of said circuits, and a contact operable in response to increase in current through said piezo electric device for rendering said electron discharge device inoperative. 35 40

11. A system for generating high frequency electrical oscillations comprising in combination an electron tube having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, a piezo electric device connected in said input circuit, a rectifying device disposed in series with said piezo electric device, a relay connected in said output circuit and connections between said rectifying device and said relay whereby an increase in current through said piezo electric device actuates said relay for opening said output circuit. 45 50

12. In a system for generating high frequency electrical oscillations the combination of an electron tube having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, a piezo electric device connected in said input circuit for controlling the operation of said electron tube, and a rectifying device connected in series with said piezo electric device and having means whereby an increase in current beyond a predetermined limit through said piezo electric device operates to open said output circuit for rendering said electron tube inoperative. 55 60 65

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