Dec. 5, 1933. J. D. WALLACE 1,938,160

METHOD OF PROTECTION OF OSCILLATION CIRCUITS

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Fig. 1.

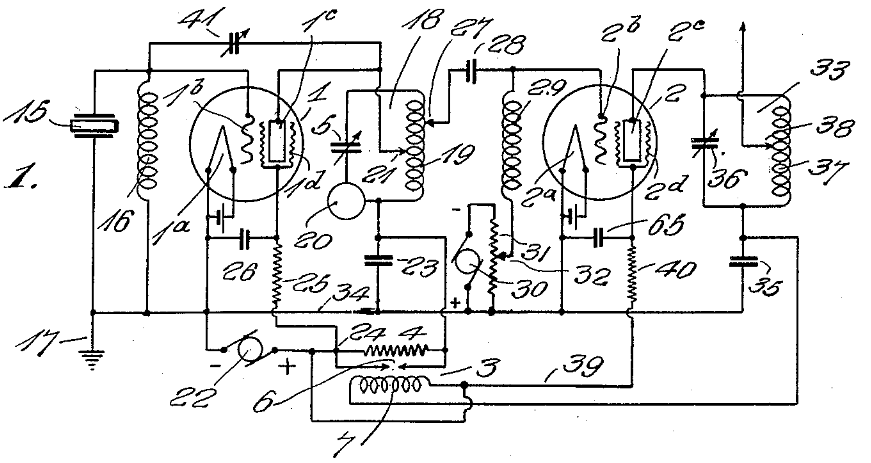


Fig. 2.

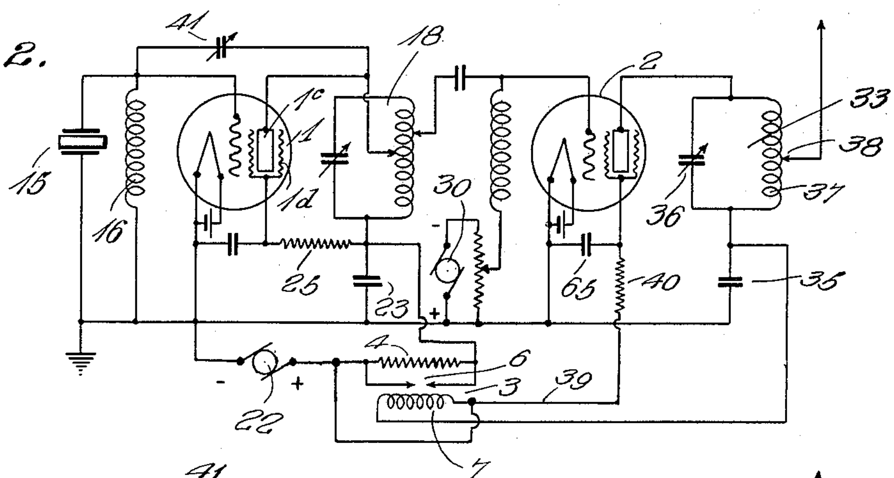
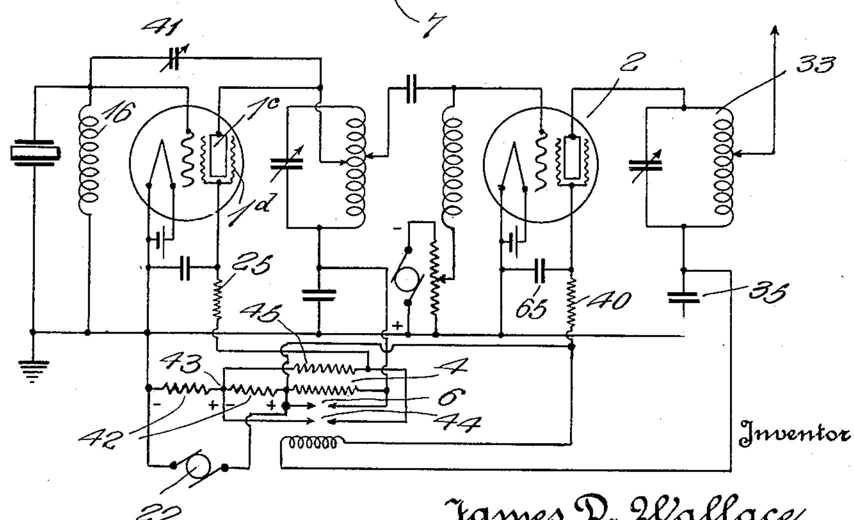


Fig. 3.



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METHOD OF PROTECTION OF OSCILLATION CIRCUITS

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Fig. 4.

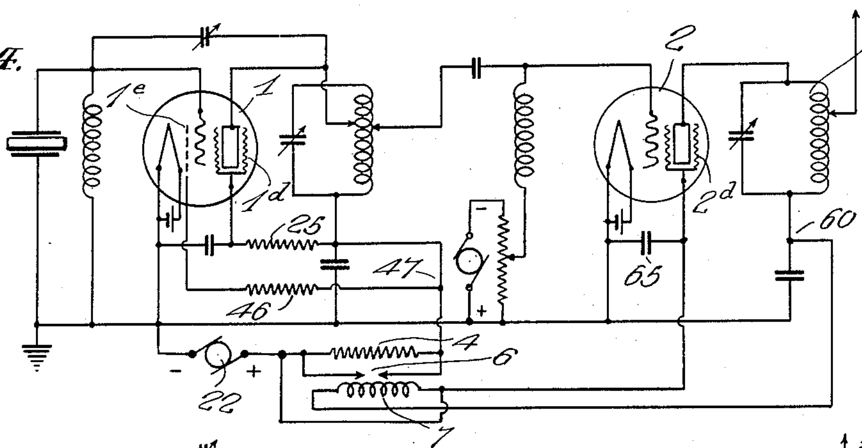


Fig. 5.

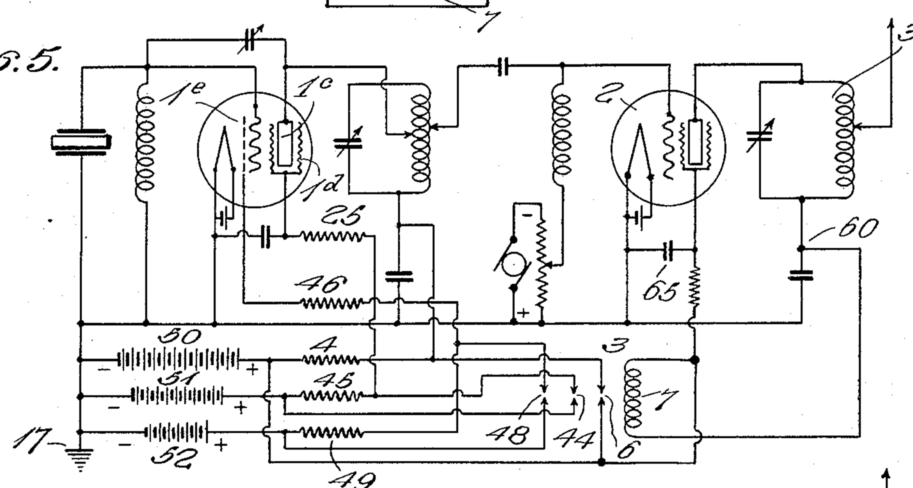
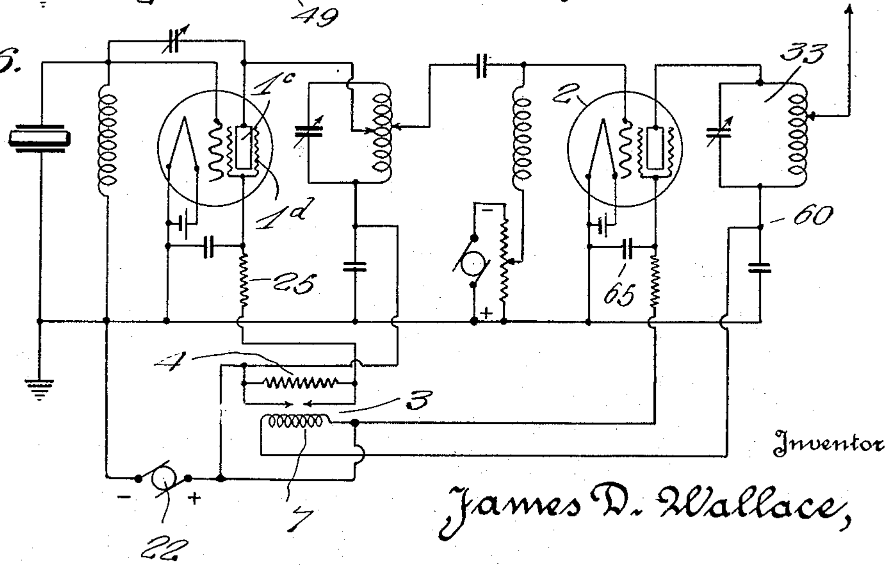


Fig. 6.



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METHOD OF PROTECTION OF OSCILLATION CIRCUITS

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Fig. 7.

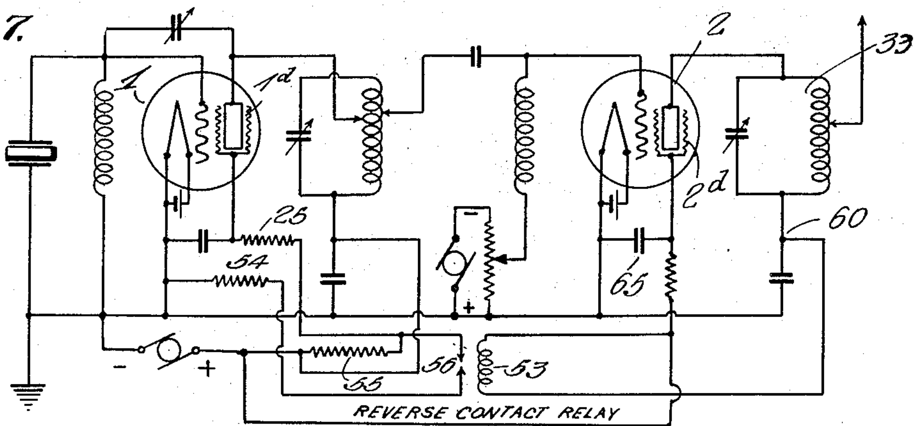


Fig. 8.

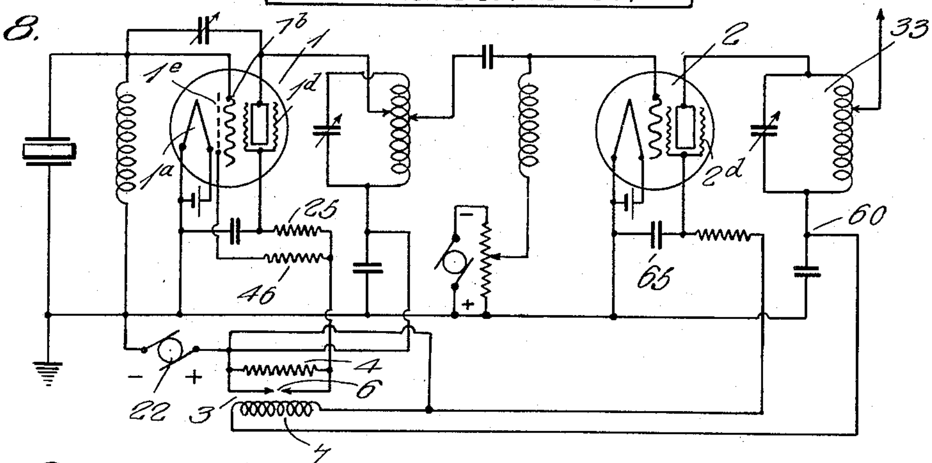
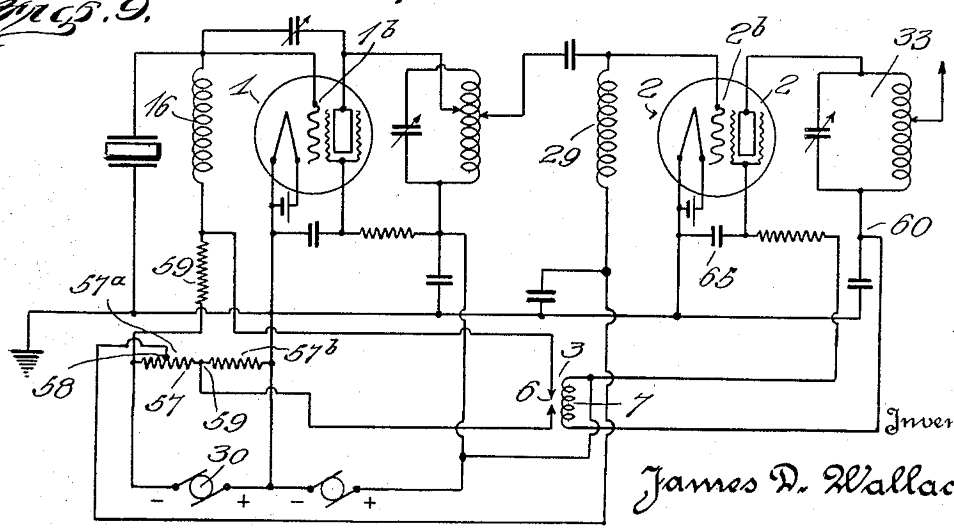


Fig. 9.



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METHOD OF PROTECTION OF OSCILLATION CIRCUITS

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Fig. 10.

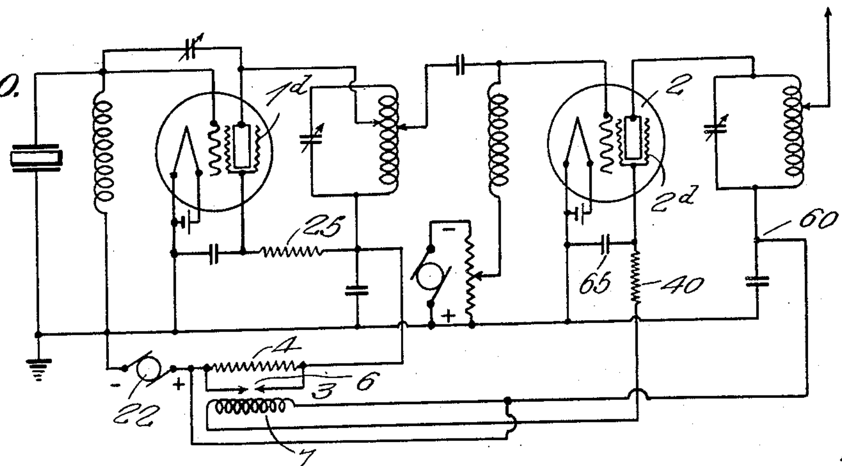


Fig. 11.

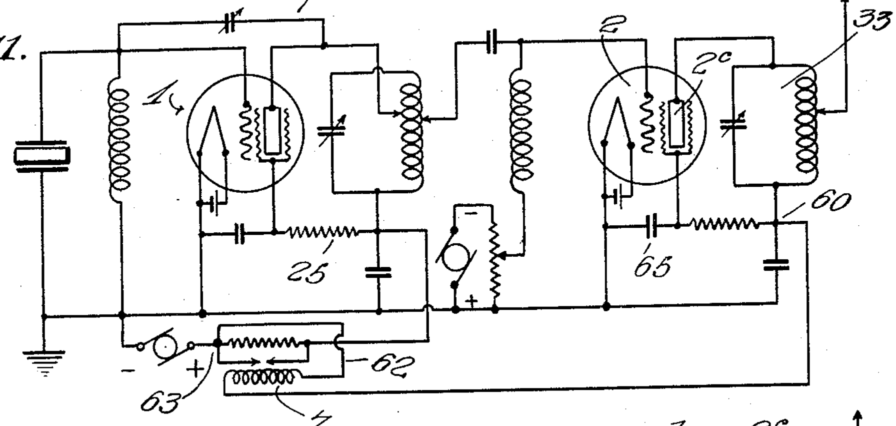
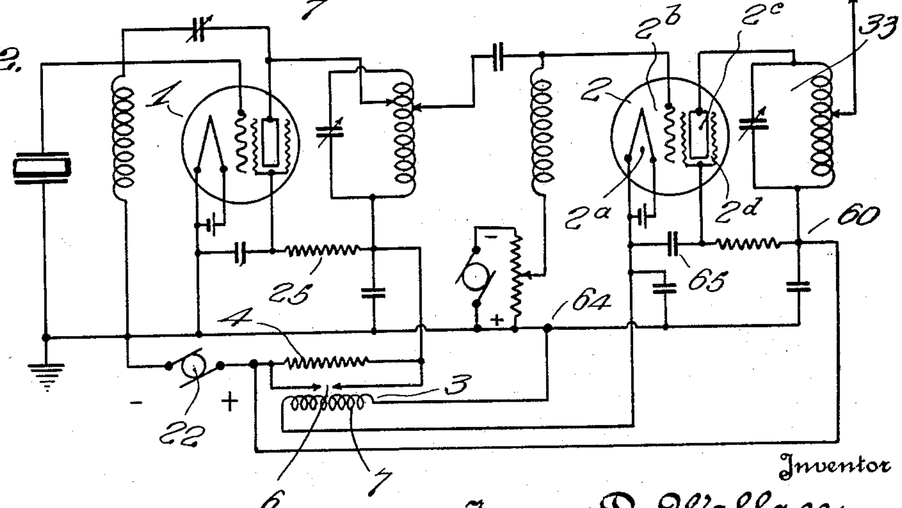


Fig. 12.



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UNITED STATES PATENT OFFICE

1,938,160

METHOD OF PROTECTION OF OSCILLATION CIRCUITS

James D. Wallace, Washington, D. C.

Application June 4, 1932. Serial No. 615,437

17 Claims. (Cl. 250—36)

My invention relates broadly to high frequency transmission systems and more particularly to a circuit arrangement for a high frequency oscillator and power amplifier circuit for signal transmission systems.

One of the objects of my invention is to provide a circuit arrangement for a high frequency transmitter in which a constant frequency controlled electron tube oscillator is electrically associated with a power amplifier in such manner that electron tubes using similar electrode potentials may be employed in both the oscillator and power amplifier stages.

Another object of my invention is to provide a circuit arrangement for a high frequency oscillator and power amplifier in a signal transmission system wherein the same source of plate potential may be employed for both the oscillator and power amplifier system with a high degree of efficiency.

Still another object of my invention is to provide a circuit arrangement for a high frequency oscillator and power amplifier system having means for automatically protecting the oscillator against excessive temperatures within the electron tube which may be produced in the event that the oscillator ceases the production of oscillations.

A further object of my invention is to provide a circuit arrangement for an electron tube oscillator and power amplifier in which the electrode potentials of the oscillator are automatically reduced when oscillations cease for avoiding conditions of overheating of the oscillator tube.

A still further object of my invention is to provide a circuit arrangement for an electron tube oscillator and power amplifier having such characteristics that it is unnecessary to employ tubes of different types in the oscillator and amplifier circuits thereby reducing the number of different types of tubes required for maintaining transmitters in operating condition.

Another object of my invention is to provide an arrangement of relay circuit controlled by the power amplifier circuits of a transmitter for controlling the operating characteristics of the oscillator system associated with the power amplifier for protecting the oscillator tube against injury due to excessive currents which may arise when oscillations in the oscillation system cease.

Other and further objects of my invention reside in the circuit arrangement for an electron tube oscillator and means for protecting such oscillator against injury as set forth more fully in the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 diagrammatically shows a circuit arrangement for an electron tube power amplifier and oscillator embodying the principles of my invention; Fig. 2 illustrates a modified form of circuit arrangement embodying my invention and in which the shield grid and plate potentials are reduced automatically when oscillations cease through the power amplifier system; Fig. 3 illustrates another form of protective circuit for an oscillation system constructed in accordance with my invention and wherein different potentials which are supplied to the shield grid and plate of the oscillator tube are interrupted on the discontinuance of oscillations through the power amplifier system in the circuit of my invention; Fig. 4 illustrates another modified form of power amplifier and oscillator connected in accordance with the circuits of my invention and wherein potentials on the space charge grid, shield grid and plate of the oscillator tube are automatically reduced upon the stopping of oscillations through the power amplifier system; Fig. 5 shows another form of circuit embodying my invention in which different potentials are supplied to the plate, the shield grid and the space charge grid of an oscillator tube and such potentials reduced upon the ceasing of oscillations through the power amplifier system; Fig. 6 illustrates another form of circuit embodying the principles of my invention and wherein the shield grid potential of an oscillator tube is reduced automatically under control of the power amplifier circuits for reducing the potential on the shield grid when oscillations cease through the amplifier system; Fig. 7 illustrates still another circuit arrangement embodying the principles of my invention whereby the potential applied to the shield grid is reduced in accordance with the action of oscillatory currents in the circuits of the power amplifier with which the oscillator tube is associated; Fig. 8 illustrates a further modified form of oscillator and power amplifier arranged in accordance with my invention and wherein the shield grid and space charge potentials are automatically reduced when oscillations cease, thereby protecting the oscillator tube against excessive temperature conditions due to rise of current through the electron discharge path in the oscillator tube; Fig. 9 illustrates another form of protective circuit embodying the principles of my invention in which the protective relay operates to increase the negative bias on the oscillator tube for reducing the current flow through the oscillator tube and preventing excessive rise in temperature conditions in the tube upon the stopping of oscillations in the oscillator and amplifier system; Fig. 10 shows a further modified form of protective circuit for oscillator systems in which the plate and shield grid potentials are reduced under control of a protective relay having the actuating winding thereof connected in the shield grid circuit of the power amplifier; Fig. 11 shows a further modified form of power amplifier and oscillator circuit embodying my invention wherein the control relay has its actuating winding connected in the shield grid and plate circuit of the oscillator and is arranged to control the shield grid and plate circuit of the oscillator for reducing the potential therein in the event that oscillations through the oscillation and amplifier systems cease; and Fig. 12 illustrates a further modified form of circuit arrangement embodying my invention in which the control relay has its actuating winding connected in the input circuit of the power amplifier with the contacts of the relay arranged in the shield grid and anode circuits of the oscillator for reducing the potential in such circuits upon the stopping of oscillations for thereby protecting the oscillator tube against injury.

My invention contemplates the protection of oscillator tubes against excessive temperature rise due to the dissipation of excessive power in the space discharge path in the tube which occurs when oscillations through the tube cease. The oscillatory currents which are normally circulated in the oscillating circuit associated with the oscillator when the oscillating system is operating under normal conditions, do not tend to produce any excessive temperature conditions with respect to the electrodes of the oscillator tube. However when such oscillations cease the potential existent on the electrodes of the oscillator tube tends to produce a current flow through the electron discharge path of the electron tube of excess proportions resulting in a temperature rise of the electrodes within the tube causing the utimate destruction or injury of the oscillator tube. In the system of my invention automatic means are provided for reducing the electrode potentials of the oscillator tube immediately upon the ceasing of oscillations in the oscillator and amplifier system. Reduction in electrode potentials applied to the oscillator tube reduces the power input to the tube and thereby eliminates danger of tube destruction. The protection which is afforded in the system of my invention is accomplished by the operation of a relay which is controlled by one or more circuits associated with the power amplifier system. When oscillations through the oscillator and power amplifier cease, relay contacts are actuated resulting in the reduction of electrode potential on the electrodes of the oscillator tube for bringing about the protection of the oscillator tube hereinbefore described.

In the design of modern crystal controlled transmitters it is quite customary to use buffer stages of amplification which are not keyed but which are operated continuously when the transmitter is being operated. The crystal oscillator rectified grid current is usually small in quantity and it is difficult to find a relay sufficiently rugged to be placed in a transmitter and yet sensitive enough to be operated by the crystal oscillator rectified grid current. If one or more buffer stages of amplification are used, the plate current drawn by any of the buffer stages may be used to operate the relay furnishing the protection.

In explaining the operation of one method of carrying my invention into effect, reference will be made to Fig. 1. A crystal controlled oscillator tube 1 is shown connected to an amplifier 2. The crystal controlled oscillator tube 1 includes a cathode 1*a*, a control grid 1*b*, an anode 1*c* and a shield grid 1*d*. The amplifier tube 2 includes a cathode 2*a*, a control grid 2*b*, an anode 2*c* and a shield grid 2*d*. The cathodes 1*a* and 2*a* may be heated from the same source of potential such as an alternating power supply circuit through a step down transformer with a midtap connection from the secondary of the transformer to each of the grid circuits. However in order to simplify the transmitter drawings, I have in each instance shown the cathodes 1*a* and 2*a* in association with a battery source as a heating means. The oscillator tube 1 has its input circuit connected between the control grid 1*b* and the cathode 1*a*, the input circuit including the piezo crystal element 15 and the radio frequency choke coil 16. The input circuit is grounded as indicated at 17. The output circuit of the oscillator includes the resonant circuit 18 comprising variable condenser 5 connected in shunt with inductance 19 through the ammeter 20. An adjustable tap 21 is taken from inductance 19 to the anode 1*c*. The output circuit is completed through contact 6 of relay 3 to the source of potential 22, returning to the cathode 1*a*. The input and output circuits of the oscillator tube 1 are coupled through the adjustable feedback condenser 41 which provides a feedback path for the production of oscillations in the oscillating tube system. A bypass condenser 23 is shunted across the power supply circuit in the output of the oscillator. The shield grid 1*d* is energized from a tap 24 in the output circuit through resistance 25. A bypass condenser 26 is connected between the shield grid 1*d* and the cathode 1*a*. The power amplifier 2 has its control grid 2*b* connected to adjustable tap 27 on inductance 19 through coupling condenser 28. The potential on control grid 2*b* is regulated by means of a circuit through radio frequency choke coil 29 from potential source 30 shunted by means of potentiometer 31 over which adjustable tap 32 may be moved. The output circuit of power amplifier tube 2 connects through resonant circuit 33 in series with the winding 7 of the relay 3 returning to the positive side of the generator 22, which in turn connects to the cathode 2*a* through common bus 34. A bypass condenser 35 is provided in shunt with the plate, power supply and relay winding 7 in circuit with the power amplifier tube 2. The resonant circuit 33 includes adjustable condenser 36 and inductance 37. A tap 38 is taken from inductance 37 to the antenna or succeeding amplifier stage. The potential for the shield grid 2*d* of the amplifier tube 2 is obtained through the connection 39 to the positive side of the generator 22 through the resistance 40 which regulates the potential on the shield grid 2*d*. The shield grid 2*d* is connected to the cathode 2*a* through condenser 65.

The relay 3 is actuated by the plate current of amplifier tube 2. A protective resistor 4 is shunted across contacts 6 of the relay 3. The operation is as follows: When the circuit is first put in operation, the tuning condenser 5 is often found not properly adjusted for producing oscillations in the crystal circuit. The resistor 4 then prevents the flow of sufficient output power to damage the tube 1. The operator adjusts condenser 5 until oscillations begin in the crystal circuit. The grid of amplifier tube 2 is then excited and amplifier plate current flows. The coil 7 of relay 3 is energized and the contacts 6 are closed, and the resistance 4 is short circuited, thereby allowing the full plate voltage to be applied to the crystal oscillator plate circuit when the oscillations begin. If for any reason oscillations cease in the crystal circuit, no excitation is applied to the amplifier tube 2, no amplifier plate current flows, and the relay winding 7 is no longer energized. The relay contacts 6 open, and the protective resistance 4 is inserted in the crystal oscillator plate circuit, thereby reducing the crystal oscillator plate voltage and furnishing protection to the tube. The crystal oscillator tube 1 shown in Fig. 1 is a shield grid tube. This method of protection has been illustrated in connection with a shield grid tube because ordinarily a three element tube used as a crystal oscillator does not have enough plate voltage applied to damage the tube when no oscillations are being produced. My invention is particularly directed to tube circuits which when used as crystal oscillator circuits employ a high plate voltage such as 2000 volts, or of such high order that the tube would be damaged if oscillations ceased. It is understood that a three or five element tube may be substituted for the crystal oscillator tube in Fig. 1 and the protection applied when necessary. A three element tube may be employed for the amplifier tube 2 in the circuit of Fig. 1 in lieu of the four element tube shown therein using neutralization circuits when necessary. This amplifier may also be replaced with a space charge grid tube of either the four or five electrode type.

Fig. 2 illustrates a modified circuit arrangement embodying my invention. The circuit of Fig. 1 has some disadvantages not present in the circuit of Fig. 2. When the resistor 4 shown in Fig. 1 is inserted in the plate circuit of tube 1 and the plate potential is lower than its normal operating point, the shield grid 1*d* may attract more than its normal number of electrons which may damage the shield grid by excessive heating. For that reason, it is advantageous to use the circuit of Fig. 2 which provides for a decrease in the shield grid potential simultaneously with the decrease in plate potential. This is accomplished by changing the circuit in such manner that the shield grid current passes through the protective resistor 4 in the plate circuit.

The resistance 25 in Fig. 2 which connects with the shield grid 1*d* is disposed in a series path which includes resistance 4 in the circuit to the generator 22. The current from generator 22 must pass through both resistances 4 and 25 when contacts 6 are open in order to reach the shield grid when there is no circulating current in the oscillator circuit, a condition which exists when contacts 6 are open. Under this condition, energy is supplied to the anode 1*c* and the shield grid 1*d* through resistance 4 and the oscillator tube is substantially protected. However, when the oscillator is functioning properly and delivering power to the power amplifier, the relay winding 7 is energized and contacts 6 are closed, thereby shunting resistor 4 and delivering the required operating potential to anode 1*c* and shield grid 1*d*. The tubes shown in the circuit of Fig. 2 may be replaced with three element tubes as described in connection with Fig. 1. If desirable, a four element tube, the inner grid of which is used as a space charge grid and the outer one a control grid, can be substituted for the crystal oscillator tube shown in Fig. 2. The circuit would be the same except that instead of supplying power to the shield grid 1*d* as in Fig. 2, provision would be made to supply voltage in a similar manner to the space charge grid. The amplifier may employ any other type of tube used in its stead provided the amplifier circuit be modified, if necessary, in such a manner as to assure proper operation.

Fig. 3 illustrates a further modified form of the crystal control tube circuit and power amplifier circuit of my invention. The source of potential 22 has a potentiometer connected in shunt therewith and illustrated at 42 with a tap connection 43 thereon. The contacts 6 and resistance 4 arranged as in Figs. 1 and 2 are now supplemented by an additional set of contacts 44 connected in parallel with an additional resistor 45 connected to tap 43 in a potentiometer. The separate resistor 45 is employed to decrease the shield grid potential of tube 1 simultaneously with the decrease in plate potential. Resistor 4 is the plate circuit protective resistor, and resistor 45 is the shield grid circuit protective resistor. The resistance 25 may or may not be used, depending upon the type of tube used. It is sometimes necessary to use a series resistor in shield grid circuits to assist the shield grid to automatically maintain approximately the correct potential. The separate resistor paths through 45 and 25 to the shield grid 1*d* and through resistor 4 to the anode 1*c* may be used whenever two different values of potential are applied to the anode and shield grid circuits, thereby assuring protection of the oscillator tube. The arrangement of the potentiometer as shown corresponds to a double voltage machine inasmuch as two different voltages may be derived from the potentiometer. The modifications of the circuit shown in Fig. 2 may also to be applied to the circuit of Fig. 3.

When a five electrode tube is used as a crystal oscillator, it is necessary to reduce the additional grid potential simultaneously with the other potential reductions. Fig. 4 shows a modified circuit of my invention by which I provide for the protection of a five electrode tube employing space charge grid 1*e*. The flow of plate current in any of the buffer stages of amplification can be used to operate a relay in connection with this system of protection. Damage to the crystal oscillator tube is prevented by the simultaneous reduction of plate, shield grid and space charge grid potentials when no oscillations are produced in the crystal circuit. In Fig. 4, the same source of potential is applied to the three electrodes, although reduced on the two grids by the insertion of resistances 4, 25 and 46, and for this reason, a relay with a single pair of contacts 6 may be used to short circuit the protective resistor 4. Resistor 25 connects as heretofore described in circuit between the shield grid 1*d* and the source of potential 22 through resistor 4. The space charge grid 1*e* connects through resistor 46 to the point 47 in the output circuit which then connects in series through resistor 4 to the source of potential 22. Under normal operating conditions with oscillations being transferred from the oscillating tube circuit to the power amplifier 2, relay winding 7 is energized and contact 6 is closed allowing potential to be supplied at predetermined values to space charge grid 1*e* and shield grid 1*d*. However, upon failure of oscillations, relay winding 7 is deenergized and contacts 6 are opened thus introducing resistor 4 into the power supply circuit and decreasing the effective potential on space charge grid 1*e*, shield grid 1*d* and anode $1c$, thereby preventing injury to the tube while oscillations are not being generated.

It is necessary to use a relay with three contacts and three protective resistors to give protection to the three circuits if separate voltage supplies are used on the three circuits or if a tapped plate supply source is used to furnish the shield and space charge grid potentials. This circuit is shown in Fig. 5 wherein the protective relay 3 has its winding 7 arranged to control the sets of contacts 6, 44 and 48. Contacts 6 are connected in shunt as heretofore shown with resistor 4. Contacts 44 are connected in shunt as heretofore described with resistor 45 while contacts 48 are connected in shunt as heretofore described with resistor 49. Separate battery supply sources have been shown at 50, 51 and 52 connected in series with the supply circuits for the different electrodes. That is, battery 50 connected in series with resistor 4 controls the energization of anode $1c$. Battery 51 connected in series with resistor 45 controls the energization of shield grid $1d$ through resistance 25. Battery 52 connected in series with resistor 49 controls the energization of space charge grid $1e$ through resistor 46. Failure of oscillations in the oscillator system and of the corresponding transfer of power to the power amplifier system results in de-energization of relay winding 7 and the simultaneous opening of the separate circuits to the different electrodes, thereby reducing the potential to a safe value and preventing heating of the oscillator tube 1 under conditions when the tube is not oscillated. If any two of the potential supply systems are common, one pair of contacts may be eliminated from the protective relay shown in Fig. 5, thereby using a relay with two pairs of contacts.

If a four-electrode tube is used as a crystal oscillator, one grid being a control grid and the other being either a shield grid or a space charge grid, it is not necessary to decrease the plate potential provided the positive potential of the other grid, shield or space charge, be reduced sufficiently to prevent enough plate power from flowing to damage the tube when no oscillations are being produced. The potential of this grid may be reduced by the insertion of a resistance in its circuit when no oscillations are being produced. The circuit shown in Fig. 6 shows a method of placing a low potential on the shield grid when the circuit is not oscillating, and automatic provision for raising it when oscillations begin. The potential is increased in this manner: The flow of the buffer amplifier plate current operates relay 3 by energizing winding 7 which short circuits the protective resistor 4. The resistor 4 is connected directly in series with the resistor 25 in the shield grid circuit including source of potential 22. When the resistance 4 is cut out of the circuit, oscillations of greater amplitude are produced in the oscillator circuit, but when the system is not oscillating, both resistances 4 and 25 are automatically connected in the circuit to the shield grid $1d$, thereby preventing the rise of current through the electron path within the tube, and avoiding undue heating of the tube. If a four element space charge grid tube is used as a crystal oscillator, the same protective circuit will apply. This circuit would be identical with the one in Fig. 6 with these exceptions: The shield grid is replaced with a space charge grid and the feed-back condenser is eliminated.

Another circuit for automatically increasing the grid potential of a four electrode tube when oscillations begin is illustrated in Fig. 7. The relay 53 is a back contact relay and is operated by the flow of plate current in one of the buffer stages of amplification. The operation is as follows: When the transmitter is started, at first no oscillations occur in the crystal circuit, and the relay contacts being normally closed, allow current to flow through resistor 54, and in this condition, resistor 55 is conducting the current flowing through the two paths, resistor 54 and resistor 55 and filament to shield grid path, and consequenly the voltage drop across resistor 55 is greater than when the flow of current through resistor 54 is broken by the relay, all of which causes the voltage between the shield grid and filament to be low at the beginning of operation. This shield grid voltage must not be large enough to cause enough plate power to flow to damage the tube. However, when oscillations begin and plate current flows in the next amplifier, the relay contacts 56 open and decreases the total current through resistor 55 and thereby increase the shield grid potential, and the plate circuit of the tube draws its normal power. If, for any reason, oscillations cease, the resistor 54 is automatically connected in the circuit and protection is given the tube. The resistor 25 is arranged in circuit with the shield grid $1d$ for controlling the shield grid voltage in a manner analogous to the arrangements heretofore described.

If a five electrode tube is used as a crystal oscillator, protection may be given the tube by causing the positive potential of the shield and space charge grids to be lowered when the crystal circuit is not oscillating. The same types of circuits shown in Figs. 6 and 7, and heretofore described, may be used to furnish protection. One of the methods is illustrated in connection with a five element tube in the diagram in Fig. 8. Electron tube oscillator 1 is shown as also including the space charge grid $1e$ intermediate the cathode $1a$ and the control grid $1b$. The relay which is employed for protecting the circuit of the space charge grid tube 1 includes the relay 3 having the winding 7 for controlling contact 6. The contacts 6 are normally open when the oscillator is not operating. However, when the oscillator commences operation, the oscillatory energy is transferred to the power amplifier circuit and the winding 7 of the relay 3 is energized thus causing contacts 6 to close, thereby shunting resistor 4 and increasing the potential on the shield grid $1b$ and space charge grid $1e$, which is the condition desired for oscillation. In the event that oscillation cease, contacts 6 are open introducing resistance 4 in circuit with the space charge grid and shield grid thereby preventing undue heating of the tube elements. The five element tube used as a crystal oscillator is protected from damage caused when no oscillations are being produced by lowering the positive potential of the space charge grid when it is necessary to limit the input power. By opening contacts 6 when the oscillations cease in power amplifier 2, resistances 4 and 46 are disposed in series with the space charge grid $1e$ and resistances 4 and 25 are disposed in series with the shield grid $1d$, thereby reducing the potential and preventing the circulation of undesired heating currents.

Protection may be given to a crystal oscillator tube for preventing damage to it by increasing the negative control grid bias with respect to the filament when no oscillations are being produced. The circuit in Fig. 9 illustrates this method. The circuit is arranged so that the oscillator tube is not blocked when the negative control grid potential is at a maximum because if it were blocked initially, no oscillations would ever start when no plate current could flow. The generator 30 which normally supplies negative bias potential for the power amplifier tube 2 is arranged to supply negative bias potential for the oscillator tube 1 through potentiometer 57. The potentiometer 57 includes sections 57*a* and 57*b*. The tap 58 on section 57*a* connects to the control grid 2*b* of power amplifier tube 2 through radio frequency choke coil 29. The negative terminal of generator 30 connects through resistance 59 and choke coil 16 with the control grid 1*b* of oscillator tube 1. This connection supplies a selected bias potential which is at a maximum and which is of such value that oscillations are nearly blocked and yet the potential is not so large that oscillations cannot start. A midtap 59 on potentiometer 57 connects through the contacts 6 of relay 3 with the grid circuit of the oscillator tube. Oscillations may be started as the negative potential is normally selected at a value substantially below blocking potential for the oscillator tube 1. Oscillatory energy is then transferred to the power amplifier circuit and relay winding 7 is energized so that contacts 6 are closed thereby decreasing the bias potential on control grid 1*b* and providing a proper bias on control grid 1*b* for the generation of oscillations. This is less than the bias which is employed in starting the oscillations. However, should oscillations cease in the power amplifier circuit relay winding 7 is de-energized and contacts 6 are opened thereby raising the grid potential to a value which lowers the space current sufficiently to prevent damage to the tube. However, the oscillations are free to start if other conditions are proper thereby energizing winding 7 and closing contacts 6 thus reducing the bias potential on oscillator 1 and enabling the oscillator to freely generate oscillations.

In the preceding figures, the relays in the protective circuits were operated by the flow of plate current in one of the buffer stages of amplification. The flow of shield grid current may be used in one or all of the buffer stages to operate a relay which would furnish protection to the crystal oscillator tube. The circuit in Fig. 10 shows the flow of shield grid current used to energize the coil 7 of the protective relay 3. The shield grid 1*d* is connected through resistance 25 with a point in the output circuit which connects through resistor 4 to the source of plate potential 22. The contacts 6 of relay 3 are maintained closed so long as coil 7 is excited by shield grid current flow in amplifier tube 2. Should oscillations cease, however, the contacts 6 are immediately opened and resistor 4 effectively placed in series in the circuit with the shield grid 1*d*, thus reducing the potential on the shield grid and preventing undue heating and destruction of the oscillator tube 1. The control current for operating the winding 7 is obtained from the circuit of amplifier tube 2, being disposed in series with the power supply to the shield grid 2*d*.

In Fig. 11, I have shown a modified form of the circuit illustrated in Fig. 10 wherein the combined plate and shield grid current of the buffer amplifier stage 2 is used to operate the protective relay 3 by connection of winding 7 to the point 60 in the output circuit of the buffer amplifier stage connecting to anode 2*c* through resonant circuit 33 and through lead 62 to the point 63 in the plate power supply system common to both oscillator tube 1 and power amplifier tube 2.

The circuits of Figs. 10 and 11 may be modified in such manner that the flow of plate, shield grid and rectified control grid current may be utilized to operate the protective relay as shown in Fig. 12. The winding 7 of relay 3 is connected to the buffer amplifier tube 2 so that one end of winding 7 connects to the cathode 2*a* and the other end of winding 7 connects at a point 64 to the common bus which is grounded. Plate potential for operation of the buffer amplifier tube 2 is obtained from generator 22 which also impresses plate potential upon the oscillator tube 1. The resistor 4 is normally shunted by contacts 6 allowing the generation of oscillations in the circuits of tube 1 so long as the contacts are held closed by energy supplied by the circuit of amplifier tube 2 to winding 7.

In the several illustrative circuits embodying my invention, a shield grid tube has been shown as the crystal oscillator tube and feedback has been accomplished through a small condenser 41 from plate to grid. The circuit has been illustrated with a shield grid tube because this protective system is necessary only with tubes operating at high plate voltages, and when high plate voltages are used, the feedback capacity should be small. In actual practice, this is usually achieved using shield grid tubes and small external condensers for allowing feedback. However, it is understood that any type of tube which will operate satisfactorily in connection with the protective circuits shown, may be used in any of the illustrated circuits as a crystal oscillator tube, modifying the circuit to produce oscillations satisfactorily, if necessary.

This protective system is required in most cases in connection with crystal oscillator tubes, since they are most likely to be improperly adjusted for producing oscillations initially. However, it is understood that the protective system of my invention may be applied to a self-oscillating master oscillator, if necessary. My invention is useful in connection with certain types of master oscillator circuits having adjustments for starting oscillations which are critical.

A shield grid tube has been shown as the amplifier in all the illustrated circuits. If desirable, a five element tube may be substituted therefor. A three element tube may be used as an amplifier tube, if the amplifier is a frequency multiplier, but if it is not a frequency multiplier, neutralization must be used.

The coil of the protective relay is shown in many of the illustrations as placed in the high potential part of the power supply circuit. It may be placed at some other point which is at a low voltage above ground, if desirable, to simplify insulation problems. Since it is difficult in some installations to provide a relay sensitive enough to operate on the value of current found in the aforementioned circuits, which has contacts which will break the circuits properly, one relay may be used to control another relay which will function satisfactorily.

The illustrations in this disclosure have shown the protective relays operated by the current in one buffer stage of amplification. It is understood that if more than one buffer stage of amplification is used, the circuits may be arranged in such a manner that the current flowing in the two or more tubes may be made to flow through the relay coil thereby making it possible to use a less sensitive protective relay.

The system of my invention permits the same source of power 22 to be employed for supplying potential for operating both the oscillator tube 1 and the power amplifier tube 2. Tubes of high power rating may therefore, be utilized directly as the oscillator for thus simplifying the construction of the transmitter and producing a greater power output at less expense.

The system of my invention has proven highly practical in operation, and, while I have described certain of the embodiments of my invention, I desire that it be understood that modifications may be made in accordance with some of the features above described and according to other features which will readily occur to those skilled in the art 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. In a system for protecting electron tube oscillator circuits, in combination, an oscillator circuit, means including a power amplifier connected with said oscillator circuit for amplifying the output energy thereof, a resistance disposed in circuit with said oscillator circuit, relay contacts connected in shunt with said resistance, a relay winding connected with said power amplifier, said relay winding operating to control said relay contacts for maintaining said relay contacts closed while oscillations are being transferred to said power amplifier and operating to open said contacts when oscillations cease for increasing the resistance of said oscillator circuit.

2. In a system for protecting high frequency oscilaltion circuits, an election tube oscillator, means including a power amplifier connected with said electron tube oscillator for amplifying the output energy thereof, a resistance element connected in circuit with said electron tube oscillator, relay contacts connected in shunt with said resistance element, and a relay winding connected with the output circuit of said power amplifier for controlling said relay contacts and maintaining said relay contacts closed under conditions of normal oscillation in said oscillator and power amplifier circuits while opening said contacts upon cessation of oscillations and increasing the resistance of said oscillator circuit.

3. In a system for protecting an electron tube, a high frequency oscillation circuit, an electron tube connected in said high frequency oscillation circuit, a power source for said oscillator tube, a power amplifier tube coupled to the output portion of said oscillation circuit, and means controlled by said power amplifier tube for modifying the character of the power supply from said power source to said oscillation circuit when oscillations transferred to said power amplifier tube cease.

4. In a system for protecting an oscillator tube, the combination of an oscillation circuit, an oscillator tube connected in said circuit, a power amplifier tube coupled to the output portion of said oscillation circuit, a power source for supplying power to said oscillation circuit, and means controlled by said power amplifier tube for reducing the power supply to said oscillation circuit when oscillations transferred to said power amplifier tube cease.

5. In a system for protecting an electron tube, the combination of an oscillation circuit, an electron tube connected with said oscillation circuit, a power amplifier tube coupled to the output portion of said oscillation circuit, a power source, a resistor electrically connecting said power source with said oscillation circuit, a pair of relay contacts connected across said resistor, and a relay winding controlled by said power amplifier for operating said relay contacts, for normally maintaining said relay contacts closed when oscillations are being transferred from said first mentioned electron tube to said power amplifier tube and effecting an opening of said contacts when oscillations transferred to said power amplifier tube cease.

6. In a system for protecting electron tubes, the combination of an oscillator tube, a power amplifier tube, oscillation circuits intercoupling said tubes, a source of potential for energizing said oscillator tube, and electromagnetic means controlled by said power amplifier tube for modifying the character of the potential supplied to said oscillator tube when oscillations in said oscillation circuit cease.

7. In a system for protecting electron tubes, the combination of an electron tube oscillator including cathode, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power supply source connected with said electrodes, a power amplifier adapted to derive oscillatory energy from said oscillation circuits, and a relay connected with said power amplifier for effecting a reduction in potential supplied to certain of said electrodes of said oscillator tube from said power supply source when oscillations in said oscillation circuit cease.

8. In a system for protecting electron tubes, the combination of an electron tube oscillator including cathode, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power supply source connected with said electrodes, a power amplifier adapted to derive oscillatory energy from said oscillation circuits, and a relay connected with said power amplifier for reducing the potential applied to at least one of said electrodes when oscillations in said oscillation circuits cease.

9. In a system for protecting electron tubes, the combination of an electron tube oscillator including cathode, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power supply source connected with said electrodes, a power amplifier adapted to derive oscillatory energy from said oscillation circuits, and a relay connected with said power amplifier for reducing a potential supplied to said shield grid and anode from said power supply source when the oscillations in said oscillation circuits cease.

10. In a system for the protection of electron tubes, an electron tube oscillator including cathode, control grid, anode, shield grid and space charge grid electrodes, oscillation circuits interconnecting said electrodes, a power supply source, connections for normally energizing said electrodes from said power supply source for effecting the generation of oscillations, a power amplifier tube coupled to and deriving oscillatory energy from said oscillation circuits, a relay comprising an actuating winding connected with said power amplifier tube, sets of contacts controlled by said relay winding, resistors disposed in circuit with each of said sets of contacts, said source of potential and said anode and said shield grid electrodes, said contacts being normally maintained closed for shunting said resistors for effecting the generation of oscillations and operating when oscillations cease in said power amplifier tube for effectively including said resistors in circuit with

said electrodes for reducing the potential supply thereto from said source of potential.

11. In a system for protecting electron tubes, an electron tube oscillator including cathode, space charge grid, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power supply source for said electrodes, a power amplifier coupled to said oscillation circuits, resistors disposed between said potential source, said space charge grid, said anode and said shield grid electrodes, a relay including an actuating winding connected with said power amplifier, and sets of contacts connected in shunt with said resistors, said actuating winding normally maintaining said sets of contacts closed when the oscillations in said oscillation circuits exist and operating to open said contacts upon cessation of oscillations in said oscillation circuit for effectively including said resistors in circuit between said potential source, said space charge grid, said anode and said shield grid for simultaneously reducing the potential thereon.

12. In a system for protecting electron tubes, an oscillator tube including cathode, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power supply source connected with said oscillation circuits, a power amplifier tube coupled to said oscillation circuits, a relay controlled by said power amplifier tube, and means actuated by said relay for modifying the potential applied between said cathode and at least one of the other electrodes when oscillations cease in said oscillation circuits.

13. In a system for protecting electron tubes, an electron tube oscillator including cathode, control grid, space charge grid, anode, and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power source for said oscillation circuits, a power amplifier tube coupled to said oscillation circuits, and means controlled by said power amplifier tube for effecting a reduction in potential from said power source on said space charge grid when oscillations through said oscillation circuits cease.

14. In a system for protecting electron tubes, an electron tube oscillator including cathode, control grid, space charge grid, anode, and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power source for said oscillation circuits, a power amplifier tube coupled to said oscillation circuits, and means controlled by said power amplifier tube for effecting a reduction in potential from said power source on both said space charge grid and said shield grid simultaneously upon the cessation of oscillations through said oscillation circuits.

15. In a system for protecting electron tubes, an electron tube oscillator including cathode, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power source connected with said oscillation circuits, a power amplifier coupled to said oscillation circuits and means controlled by said power amplifier for effecting an increase in negative potential on said control grid with respect to the filament from said power source upon cessation of oscillations in said oscillation circuits.

16. In a system for protecting electron tubes, an electron tube oscillator including cathode, control grid, anode and shield grid electrodes, a power source connected with said oscillation circuits, a power amplifier coupled to said oscillation circuits, a relay controlled by said power amplifier and circuits actuated by said relay for effecting an increase in potential on the control grid of said oscillator tube when oscillations through said oscillation circuits cease.

17. In a system for protecting electron tubes, an electron tube oscillator including cathode, control grid, anode and shield grid electrodes, oscillation circuits interconnecting said electrodes, a power source for said oscillation circuits, a power amplifier coupled to said oscillation circuits, means for applying a predetermined potential on said control grid from said power source for sustaining a normal condition of oscillation in said oscillation circuit, a relay controlled by said power amplifier tube and means actuated by said relay for modifying the potential on said control grid when oscillations through said oscillation circuits cease.

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