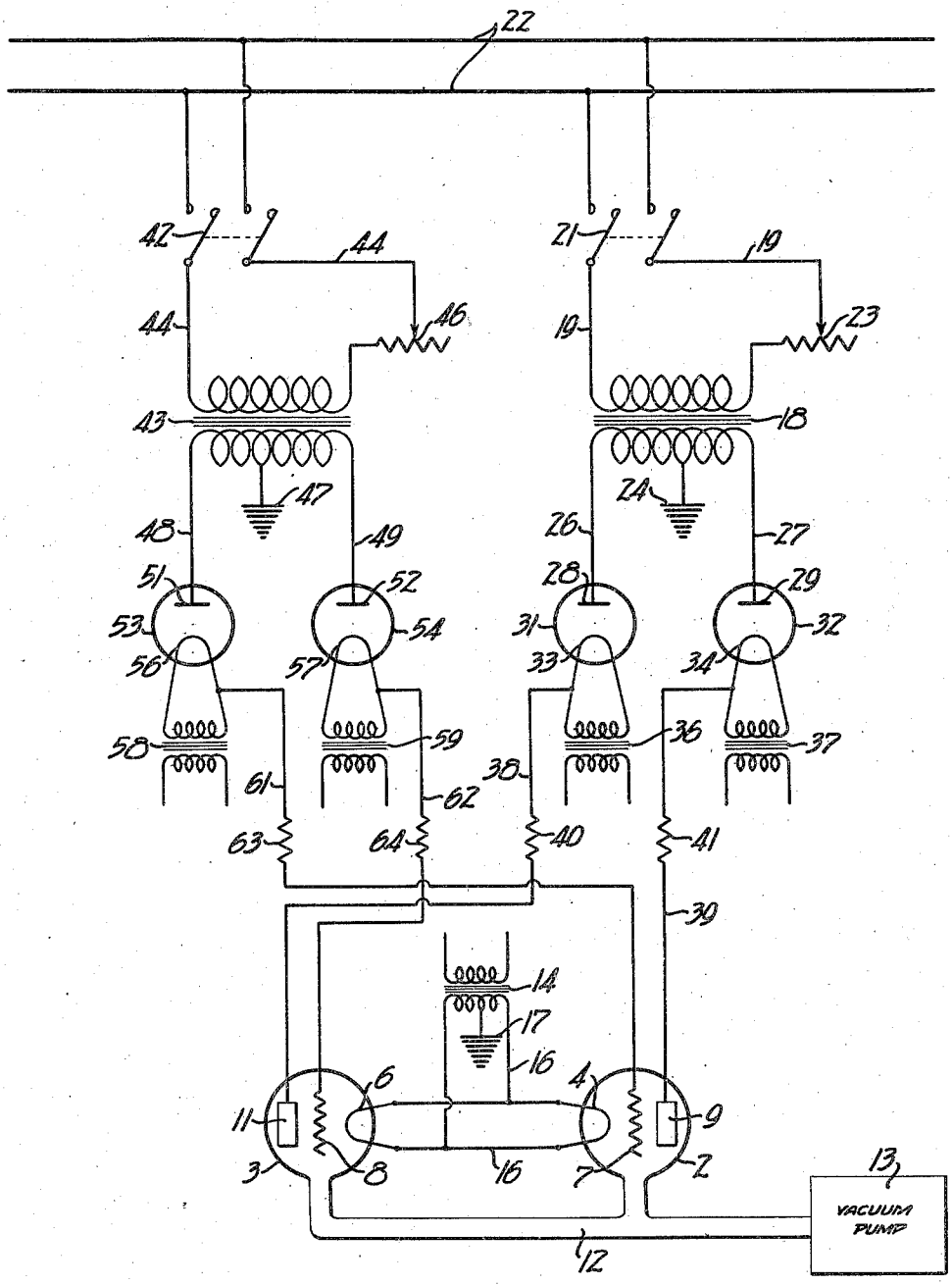
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METHOD AND APPARATUS FOR EXHAUSTING TUBES

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METHOD AND APPARATUS FOR EXHAUSTING TUBES

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Our invention relates to the outgassing of elements in a vacuum tube; and the broad object of our invention is to provide an improved system for heating the elements of a tube during evacuation to remove the occluded gas in the metal.

Another object of our invention is to provide means, in a system of the character described, for independently heating and separately controlling the temperature of the elements, whereby the latter may be heated either independently or at the same time, and to any desired temperature.

Still another object of our invention is to provide a system for evacuating tubes which decreases the time and cost of manufacture, and at the same time produces a "harder" tube.

A further object of our invention is to provide an improved method of cleaning the tube elements.

The invention possesses other objects and features of advantage, some of which with the foregoing, will be set forth in the following description of our invention. It is to be understood that we do not limit ourselves to this disclosure of species of our invention, as we may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawing:

The figure of the drawing is a diagrammatic view showing apparatus embodying the improvements of our invention.

In terms of broad inclusion, our method of treating a tube having an element to be outgassed comprises providing a source of electrons, bombarding the element with the electrons to heat the element to drive out its occluded gas, evacuating the tube while the element is being heated, and regulating the electron bombardment to control the temperature of the element.

In a tube having a plurality of elements to be outgassed the latter are heated concurrently by alternately bombarding the elements. Our preferred method of heating a plurality of elements comprises first bombarding one of the elements to drive out the occluded gas, then bombarding another element to drive out its occluded gas, and then alternately bombarding both of the elements to concurrently heat the latter for driving out the remaining occluded gases therein at the same time.

The apparatus of our invention broadly comprises means for exhausting a tube; means for heating an element in the tube to provide the electron emitting element; and means for impressing pulses of positive potential on the other elements of the tube to bombard the latter elements with electrons from the emitting element. Selector means are also provided for impressing the pulses either on a selected one of the elements, or alternately on a plurality of the elements to be heated; and means are further provided for regulating the pulses to control the temperature of the element or elements being heated.

In greater detail, and referring to the drawing, the method and apparatus of our invention is illustrated in connection with the evacuation of a plurality of thermionic tubes **2** and **3**, having filaments **4** and **6**, grids **7** and **8**, and plates **9** and **11**, respectively. The single phase system shown operates to evacuate a pair of tubes, but more tubes may be treated at one time if desired by using polyphase systems. For purposes of illustration a pair of triodes are shown, but it is understood that tubes with additional elements may also be treated.

For use with our process of evacuation we employ tubes having grids and plates of a material having a high melting point, such as tantalum. These elements are carefully cleaned before mounting within the glass envelopes. The grid structures are preferably cleaned by etching with hydrofloric acid, but the plates are given a special treatment. Plates are usually cleaned by sand blasting, but particles of sand adhering to metal are difficult if not impossible to remove. In order to overcome this difficulty we blast with fine particles of steel, and subsequently dissolve the steel particles adhering to the plate. The cleaning fluid used is preferably a boiling solution of chromic acid, sulfuric acid and water. After being immersed in this solution the plates are boiled in distilled water.

The assembled triodes are connected by an exhaust tube **12** to a suitable evacuating means **13**. A mercury vapor pump in series with a mechanical pump is preferably employed, the latter operating as a roughing pump to rapidly reduce the pressure at the beginning of the pumping operation. Of course it is understood that this is merely for purposes of illustration and that any suitable pumping means may be used.

While the pump means **13** is operating to reduce the pressure in the tubes, the glass envelopes of the tubes are baked in the usual manner by ovens lowered over the tubes. In these ovens the bulbs are heated to as high a temperature as is safe for the Pyrex glass preferably used. This heating drives out the occluded gas in the glass.

After outgassing the glass envelopes, the fila-

ments 4 and 6 are heated to provide electron emitting elements. The current for heating the cathodes is preferably supplied by a suitable transformer 14 having its secondary winding connected to the electron emitting elements by leads 16. The center of this secondary winding is grounded as indicated at 17.

After the filaments have been heated, and while the pump is still operating, the plates 9 and 11 are subjected to pulses of positive potential, so that the plates are periodically made positive with respect to the filament. By doing this the plates are intermittently bombarded with electrons pulled over from the filament; this bombardment resulting in the plates becoming heated by the kinetic energy given up to the plates when the rapidly moving electrons are suddenly stopped.

The reason for using separate pulses on the plate is that another element in the same tube, such as the grid, may be subsequently supplied with alternate pulses to effect heating of both elements at the same time, as will hereinafter be described. At first however the plate only is heated. While the bombardment of the element is intermittent, due to the periodic character of the pulses, the mass of the element tends to hold the temperature substantially constant during the short intervals between pulses. As a result the temperature of the bombarded element is elevated uniformly and may be held constant at any predetermined temperature, depending on the potential of the plate.

In our process the plate is elevated to a temperature sufficient to drive out the occluded gas. We find that tantalum gives up most of its gas at about 800° C. which is considerably lower than for most other metals. The plates are brought up to a bright red heat and held there until the current in the plate circuits reaches a steady value, indicating that the plates are outgassed.

The means for supplying the pulses to the plates preferably comprises a transformer 18 connected by leads 19 through a switch 21 to supply lines 22 carrying a single phase alternating current. For purposes of regulating the pulses delivered to the plates an adjustable resistor 23 is provided in the primary circuit of the transformer. This resistor regulates the potentials of the plates, and therefore provides means for controlling the temperature to which the plates are elevated.

The secondary winding of transformer 18 is grounded at its center as indicated at 24, and the ends of the winding are connected by leads 26 and 27 to anodes 28 and 29 of a pair of diodes 31 and 32. Cathodes 33 and 34 of these rectifiers are heated by current from suitable transformers 36 and 37. Cathode 33 of diode 31 is connected by lead 38 to plate 11 of tube 3 being evacuated; and cathode 34 of diode 32 is connected by lead 39 to plate 9 of the other tube 2. By this arrangement the plates receive pulses, one on each half cycle.

In order to protect the circuits against excessive currents that might be occasioned by ionized gas in the tubes, suitable current limiting resistors 40 and 41 are interposed in the leads 38 and 39. These resistors each preferably comprise a bank of lamps having tungsten filaments. The advantage of using such lamps is that the resistance of the filaments goes up with the temperature, thereby automatically regulating the excessive gas currents. Another advantage of the lamps is that they provide a visual indication of gassing in the tubes.

After the plates have been outgassed, the pulses are removed from the plates and similar pulses are impressed on the grids 7 and 8 by opening switch 21 and closing a second selector switch 42 to cut in a second transformer 43; the latter being connected to the lines through switch 42 by leads 44. A resistor 46 is also provided in the primary circuit of this transformer to control the pulses impressed on the grids.

The secondary winding of this transformer is also grounded at its center as indicated at 47, and is connected by leads 48 and 49 to anodes 51 and 52 of a second pair of diodes 53 and 54. Cathodes 56 and 57 of the latter are heated by current from suitable transformers 58 and 59. These cathodes in turn are connected by leads 61 and 62 to the grids 7 and 8 respectively of the triodes. Suitable current limiting resistors 63 and 64, similar to those provided in the plate circuits, are also interposed in the grid circuits. By this arrangement the grids may be bombarded independently of the plates and separately heated to drive out the occluded gas.

The treatment to this point eliminates most of the gas in the elements, but while outgassing the grid a portion of the latter gas is absorbed by the plate. Because of this phenomenon, it is highly desirable to finally heat both grid and plate to a high temperature at the same time. This is readily accomplished in our improved apparatus by merely closing both the selector switches 21 and 42 to energize transformers 18 and 43 at the same time. As a result the plate 11 of tube 3 and grid 7 of tube 2 both receive a pulse during one half the cycle, and the plate 9 of tube 2 and grid 8 of tube 3 receive a pulse during the other half of the rectified cycle.

In other words, the plate and grid in each tube receive alternate pulses, and alternately go positive with respect to the filament of that tube. This causes the elements to be alternately bombarded, thereby effecting the desired independent but concurrent heating of the plate and grid. As a result both the elements may be maintained at the high temperature necessary for the complete elimination of occluded gases. This control would not be possible if both grid and plate were made positive at the same time, due to the accelerating effect of the grid on the electron stream.

By adjusting the resistors 23 and 46 in the primary circuits of transformers 18 and 43 the relative temperatures of the plates and grids in the tubes being evacuated may be varied. Thus if it is desired to alter the temperature of one pair of elements, it is only necessary for an operator to adjust the corresponding resistor to vary the pulse impressed on the elements. If the potential on the elements is increased the corresponding increase in the electron bombardment results in an increased temperature, while a decreased potential causes a lowering in the temperature, as will be readily understood.

During this heating of the plates and grids together the elements are preferably elevated to a very high temperature, say in the order of 2000° C. At this temperature the plates and grids are incandescent. This insures that all the gases are eliminated, and produces a tube which is very "hard", with fixed and dependable characteristics. After the final heating the switches 21 and 42 are opened and the tubes sealed off the pumps in the usual manner.

Another advantage of our system is that the grid may be separately heated to a point where electronic emission takes place, so that the cathode is virtually moved to the surface of the emitting grid, for the purpose of bombarding the plate. This is desirable in high impedance tubes since it operates in effect to lower the impedance of the tube and allows the plate to be heated to the desired temperature without the use of high voltage.

Still another advantage of the system is that it secures a high vacuum without the use of "getters", such as magnesium. These volatile getters dirty the tubes and are highly undesirable. In our process the tantalum elements, being thoroughly outgassed, function as getters to absorb much of the residual gases. In our tubes the vacuum secured is in the order of 10^{-7} mm. Hg.

A still further advantage of our system of evacuating tubes is that it effects a material saving in time. We are able to evacuate in less than two hours tubes which take about seven hours to evacuate by the usual radio frequency induction method. Furthermore, our system has the advantage of being capable of automatic operation, as will be readily appreciated.

With the single phase system shown a pair of tubes may be treated at the same time, one on each half cycle. Such an arrangement also prevents the direct current from saturating the transformers. If desired two or three phase systems may be used; in the former two or more tubes may be treated, and in the latter three or more tubes may be handled. It is also understood that the use of a rectified alternating current for supplying the pulses is merely for purposes of illustration; the pulses could be supplied by a commutated machine, as well as a rectifier.

It is further understood that our method of heating an element in a vacuum tube, or concurrently heating a plurality of elements in a tube, may be used for purposes other than driving out occluded gas during evacuation; in fact, our method may conveniently be employed whenever it is desired to heat elements in an evacuated tube.

We claim:

1. The method of treating a tube having a plurality of elements to be outgassed, which comprises evacuating the tube, and without admitting gas to the tube alternately bombarding the elements with electrons to concurrently heat the elements for driving out the occluded gases therein at the same time.

2. The method of treating a tube having a plurality of elements to be outgassed, which comprises alternately bombarding the elements with electrons evaporated from a heated surface to concurrently heat the elements for driving out the occluded gases therein at the same time.

3. The method of treating a tube having a plurality of elements to be outgassed, which comprises bombarding one of the elements with electrons to separately heat said element to drive out the occluded gas, bombarding a second element to separately heat the latter for driving out its occluded gas, and then alternately bombarding both the elements to heat them together for driving out the remaining occluded gas in both elements at the same time.

4. The method of treating a tube having a plurality of elements to be outgassed, which comprises heating one of the elements to provide a source of electrons, and alternately bombarding other elements in the tube with said electrons to concurrently heat the latter elements for driving out the occluded gases therein at the same time.

5. The method of treating a tube having a plurality of elements to be outgassed, which comprises providing a source of electrons, and impressing pulses of positive potential only on first one and then another of the elements to effect alternate bombardment of the latter with electrons from said source to concurrently heat the elements for driving out the occluded gases therein at the same time.

6. The method of treating a tube having elements to be outgassed, which comprises providing a source of electrons, rectifying an alternating current to provide pulses of positive potential, and impressing successive pulses on alternate elements to effect bombardment of the latter with electrons from said source to heat the element for driving out the occluded gas.

7. The method of treating a tube having a plurality of elements to be outgassed, which comprises evacuating the tube to such a degree that gas ionization will be negligible, and while said tube is in that condition alternately bombarding the elements with electrons to concurrently heat the elements for driving out the occluded gases therein at the same time.

8. The method of treating a tube having a plurality of elements to be outgassed, which comprises evacuating the tube to such a degree that gas ionization will be negligible, and while said tube is in that condition heating one of the elements to provide a source of electrons, and then alternately bombarding other elements with said electrons to concurrently heat the latter elements for driving out the occluded gases therein at the same time.

9. The method of treating a tube having a filament and a grid and plate to be outgassed, which comprises heating the filament to provide a source of electrons, impressing a positive potential on the plate alone to separately heat it for driving out its occluded gas, then impressing a positive potential on the grid alone to separately heat it for driving out its occluded gas, and then impressing pulses of positive potential on first one and then another of the latter elements to concurrently heat said elements for driving out the remaining occluded gas.

10. The method of making a tube having a filament, grid and plate, which comprises cleaning the plate, mounting the elements in the tube, evacuating the tube to such a degree that gas ionization will be negligible, heating the filament to provide a source of electrons, impressing a positive potential on the plate alone to separately heat it for driving out its occluded gas, then impressing a positive potential on the grid alone to separately heat it for driving out its occluded gas, and then impressing pulses of positive potential on first one and then another of the latter elements to concurrently heat said elements for driving out the remaining occluded gas.

11. The method of electronically bombarding an element in a tube having a filament, which comprises heating the filament to provide a source of electrons, bombarding the element with electrons emitted from the filament until said element emits electrons, and blocking flow of electrons from said element to the filament to prevent bombardment of said filament.

12. The method of electronically bombarding elements in a tube having a filament, which com-

prises heating the filament to provide a source of electrons, bombarding an element with electrons emitted from the filament until said element emits electrons, blocking flow of electrons from said element to the filament to prevent bombardment of said filament, and bombarding a second element with electrons emitted from the first element.

13. The method of electronically bombarding elements in a tube, which comprises providing a source of electrons, impressing pulses of positive potential on an element to effect bombardment thereof with electrons from said source to heat said element to a point where it emits electrons, and impressing pulses of positive potential on a second element during periods when no potential is applied to the first element to bombard the second element with electrons emitted by the first element.

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