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INDUCTION HEATING OF ENCLOSED ELEMENTS

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Fig. 1.

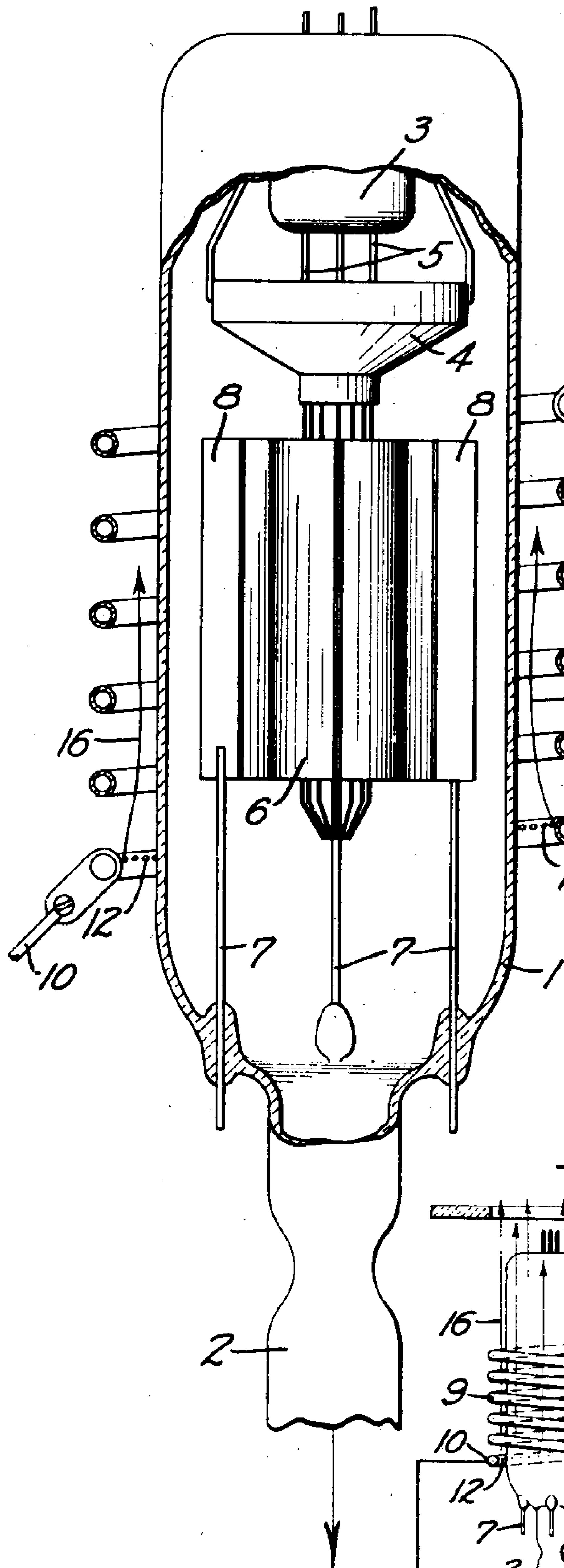


Fig. 2.

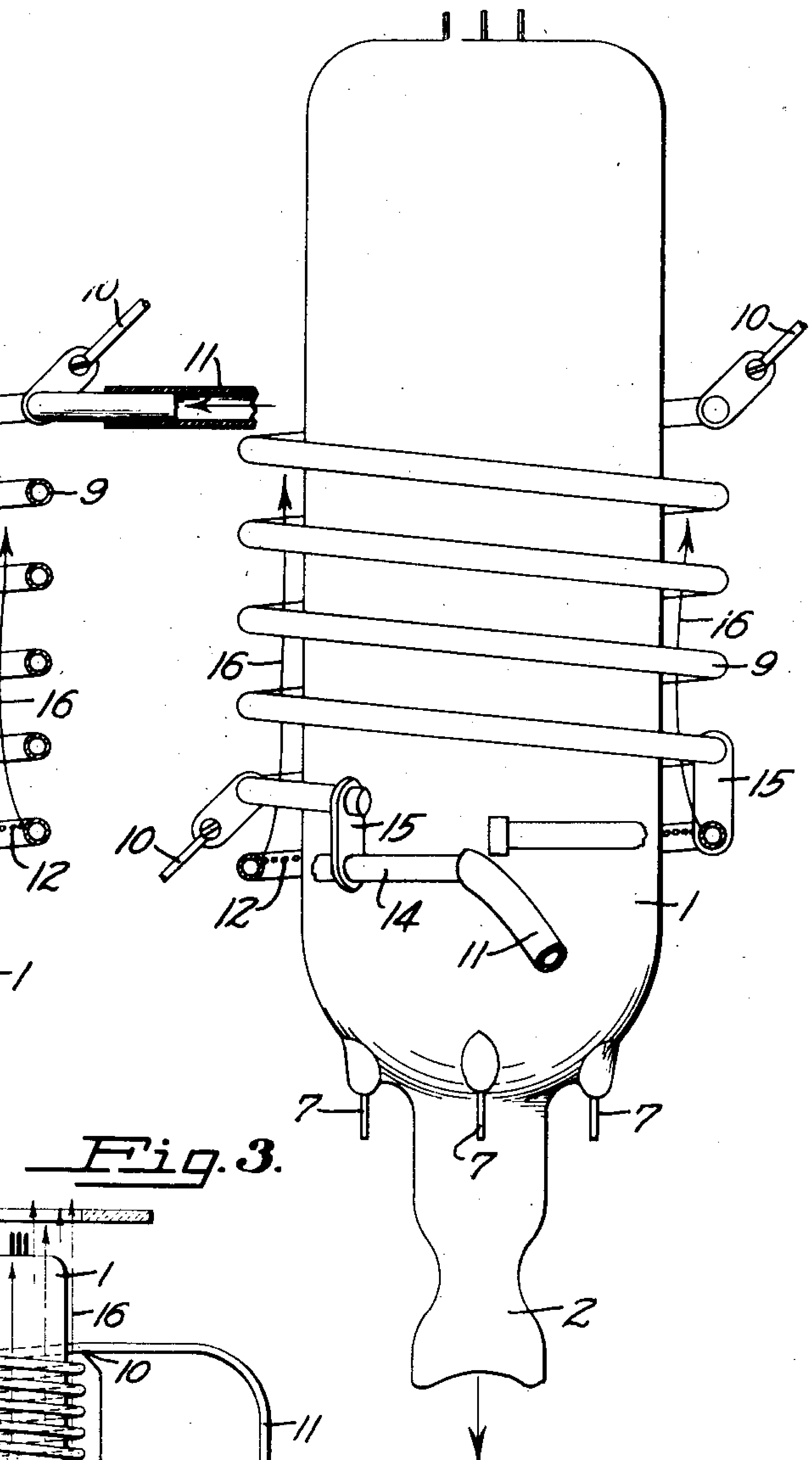
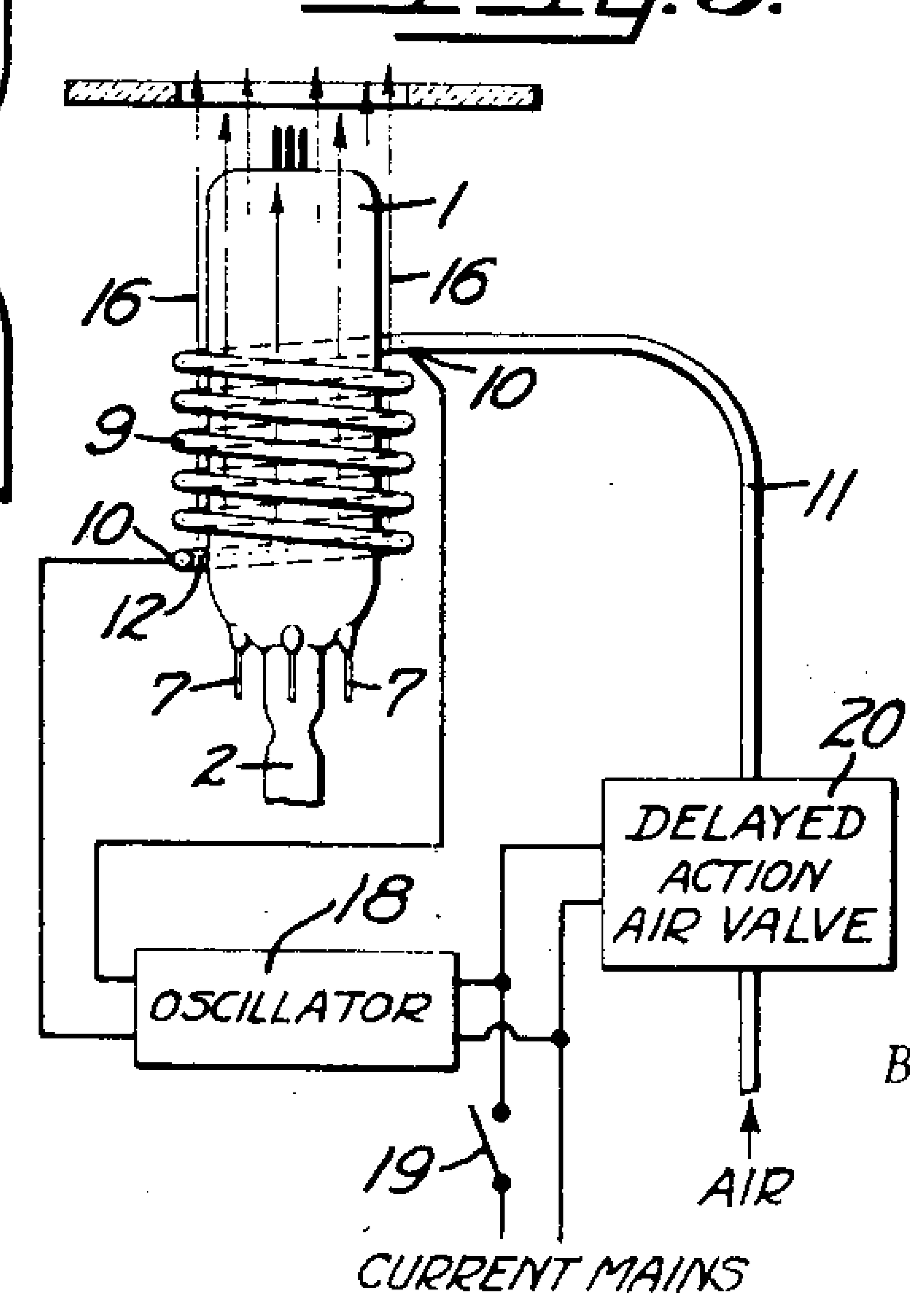


Fig. 3.



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INDUCTION HEATING OF ENCLOSED ELEMENTS

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7 Claims. (Cl. 250—27.5)

Our invention relates to a means and method of inductively heating the elements of a thermionic tube, or like device, during the evacuation thereof, and more particularly to a means for supplying large amounts of high frequency power to an inductance acting on a thermionic tube element during evacuation.

The principal object of our invention is to provide an improved arrangement, in conjunction with a thermionic tube under evacuation, for heating the electrodes in the tube to exceptionally high temperatures by induction.

A further object of the invention is to prevent collapse of the envelope during such induction heating, and a still further object is to provide a means and method for heating electrodes by induction to high temperatures in an envelope having walls placed relatively close to said electrodes.

Other objects of our invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but we do not limit ourselves to the embodiment of the invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawing:

Figure 1 is a longitudinal view, mostly in elevation, of a thermionic tube having a high frequency coil surrounding the envelope. A portion of the envelope has been broken away to show the interior electrodes, and the coil is shown in section.

Figure 2 is a longitudinal view, in elevation, showing a modification of the bombarder coil shown in Figure 1.

Figure 3 is a diagram of an arrangement interconnecting the application of current and air.

It is well known in the art that in the production of thermionic tubes of high power, which are used largely for radio transmitting purposes, that it is necessary to thoroughly out-gas the electrodes during evacuation of the tube. This out-gassing is commonly accomplished by the use of an eddy current coil carrying high frequency disposed around the exterior of the envelope to heat the interior electrodes by induction therefrom.

The increasing popular use of highly refractory metals for the interior electrodes of such tubes has allowed higher and higher temperatures to be used in the electrodes during out-gassing, and this in turn has given rise to new problems. When tantalum or tungsten is used, for example, as the material of which anodes are made in thermionic tubes, it is possible, without materially harming the anodes, to heat them to white heat by the induction of eddy current therein. If the anodes, which will be used as convenient examples of materials to be heated, throughout the discussion following, are positioned relatively close to the envelope, the envelope will be heated, unless care is taken, to a temperature where it will soften and suck in under the influence of the vacuum pump. This action places a definite limitation on the temperature to which the anodes may be heated, and also on the time during which the heating may be continued.

If, in order to eliminate the danger of sucking in, the envelope is made large enough to be a sufficient distance away from the anodes during the process to remain relatively cool, the efficiency of the induction procedure falls rapidly, as the eddy current coil is, in practice, placed outside of the envelope. There is a large loss of power in the transference of energy from the coil to the electrode, due to the distance therebetween.

Furthermore, when a bombarder coil is supplied with large amounts of high frequency current, the metal of the coil itself heats. This heat, reaching the envelope, in addition to that coming from the interior, adds a further limitation to the processing. Furthermore, the application of any cooling arrangement to a tube during the processing thereof must be done with such care that sudden changes in temperature are avoided, otherwise strains will be set up in the envelope which may not only crack the envelope during the processing, but which will lay the foundation for a latent defect which can occur after the tube has been placed in service.

In investigating the problems involved in heating refractory anodes to extremely high temperatures, particularly in tubes where the anodes are placed relatively close to the envelopes, we have found that it is possible to supply specially large amounts of high frequency power to an induction coil placed closely around an envelope and thereby heat anodes to temperatures which approach the disintegration temperatures of the refractory metals. Furthermore, we are able to continue this heating over relatively long periods of time without danger to the envelope either from excessive heating or the development of strains therein.

Broadly speaking, our invention comprises the use of a high frequency coil in combination with an envelope to be evacuated, and a stream of air controlled in shape and passed between the bombarder coil and the envelope, preferably at high velocity, during the heating process. We may also prefer to control, in addition to the shape of the stream of air, the time of application with respect to the time of application of the high frequency current.

The various aspects of our invention may be more fully understood by reference to the figures and to the following description of the evacuation process utilizing our invention:

Referring directly to Figure 1, a thermionic tube envelope 1 is provided at one end with an exhaust tube 2 and at the other end with a reentrant stem 3. In this case the reentrant stem 3 carries a skirted grid 4 and a cathode, not seen, supported by cathode leads 5. An anode 6 is supported from the exhaust end of the tube by risers 7. The anode here is of cylindrical shape, preferably formed from a refractory metal such as tantalum or tungsten, and provided with radiating fins 8. In view of the results obtained by the use of our invention, we are able to place the walls of the envelope 1 quite close to the anode 6, as shown. It is obvious, however, that the process to be described is applicable to any type of envelope wherein metal objects are mounted.

Around the outside of the envelope we dispose a coil 9, preferably of hollow section, having end terminals 10 for electrical connection to a circuit, such as a high frequency oscillator, for the circulation of high frequency current therein.

As thermionic tubes, during processing, are generally mounted in a vertical position, as shown, we prefer to leave the upper end of the coil 9 open and close the lower end. We then attach a tube 11 to the open end. This tube is preferably of rubber hose, or other insulating material, and the hose is connected to an air supply which is under the control of a valve or similar device. We then perforate the lower turn of the inductance with a series of air apertures 12, drilled at such an angle that air escaping therefrom will be directed in a thin cylindrical sheet between the turns of the coil 9 and the envelope. The air, passing through the upper turns of the inductance before release, cools the inductance during its progress through the coil to the apertures 12.

In the modification shown in Figure 2, both ends of the bombarder coil are closed, or left open if desired, and the air is supplied by a broken turn 14 held in position below the bombarder by insulating spacers 15. The air apertures in this latter case will be drilled to direct the air in exactly the same manner as in the embodiment shown in Figure 1.

It is quite customary, in pumping thermionic tubes, to do considerable preliminary exhausting while the tubes are being baked in an oven and heated to a temperature as great as the envelopes can safely stand. We also include this step in our preferred pumping procedure. When this preliminary exhausting has been completed we prefer to open the oven and place over the tube the combination bombarder and air director. High frequency is then supplied to the coil, and as soon as the anode 8 reaches a cherry red temperature, or such a temperature which will begin to heat the walls of the envelope to a dangerous degree, air is supplied through the hose 11 and the sharply defined cylindrical stream passed between the envelope and the coil, as indicated by the arrows 16 in both figures. As we do not care to cool off the oven as a whole any more than is necessary, we prefer to provide a round aperture in the top of the oven through which the directed air, passing upwardly, may leave the oven.

We also prefer to supply the air at a relatively high velocity and this velocity may be regulated by means of a valve to keep the envelope walls at the proper temperature to avoid strains forming therein. The air, when directed as described, remains in a relatively sharply defined column after leaving the envelope and is easily passed out of the oven through the overhead apertures. These apertures, of course, may be provided with covers when the oven is being used for baking purposes.

Air is released during the entire full temperature period, and by supplying large amounts of high frequency power to the coil 9, the anode may be heated to a white intensity over relatively long periods of time. For example, we have been able to supply better than five kilowatts of power to the coil maintaining an anode white hot over long time periods, when the spacial relationships of the elements involved were practically identical with those shown in the drawing, and where the envelope was only two and one half inches in diameter. In this way we have been able to produce power tubes which are exceptionally hard and which show no release of gas, even when operated in service at several times their rated capacity.

When the anode has been sufficiently heated the high frequency is cut off from the coil, but we prefer not to immediately cut off the air. We prefer to wait until the anode has cooled to a point where it cannot excessively heat the envelope and then shut off the air.

In order to make our inductive heating process more nearly automatic, we may desire to utilize an arrangement, as shown in Figure 3. Here the oscillator 18 is under the control of a main switch 19. Current from the mains is also passed, under control of the same switch, through a delayed action, electrically operated air valve 20. This air valve will be so adjusted that the air will be released as the temperature of the anode rises to the danger point, and continue after the oscillator has been shut off until the anode has properly cooled. In this manner proper time correlation of current and air may be made uniform when a number of tubes are to be processed.

It should be noted that the air, passing between the coil and the envelope, cools them both, and that the coil shown in Figure 1 is further cooled by the air passing through it. As it is customary to pump a number of tubes on the same manifold at the same time, it will be seen that the method of applying air, as described above, confines the cooling not only to a single tube but also to a specified portion of the particular envelope. The process, therefore, differs radically from any process of blowing air through the entire oven, or any gross application to one or more envelopes. The processing by induction of one tube does not, in any way, change the heat conditions of the tube next to it, the air passing out above the tube without playing on its neighbor. The oven itself is not cooled other than by opening. Heat conservation throughout the device is good because the air is applied only at the point where it is needed, kept in a predetermined path, and directed away from others.

Furthermore, it is quite possible to permanently build the bombarder coils in position in an oven by combining connection 10 and tube 11 into a metal pipe leading to the oscillator, and there supplying the air through an insulating hose. Each tube may thus be separately processed without disturbing any other tube, and the oven need not be opened, except to uncover the air outlet aperture above the tube being processed.

We have found that in thermionic tubes, processed as described above, a higher vacuum can be obtained in a much shorter time than with methods heretofore in vogue. Modifications of our apparatus, and applications of our method, will be apparent to those skilled in the art, the particular embodiment shown being used for purposes of illustration only.

We claim:

1. In combination with a hollow coil carrying high frequency currents and adapted to be placed around an envelope to heat electrodes therein by induction, means for supplying air under pressure to one end of said coil, and means for releasing said air from said coil circumferentially around the opposite end turn of said coil, said released air being directed to pass between the turns of said coil and said envelope.

2. In combination with a hollow coil carrying high frequency currents and adapted to be placed around an envelope to heat electrodes therein by induction, said coil having an open end and a closed end, means for supplying air under pressure to said open end, the last turn of said coil adjacent said closed end having a series of spaced apertures adapted to direct air released therethrough between the remainder of said coil and said envelope.

3. In combination with an eddy current coil adapted to be placed around an envelope wherein electrodes are mounted, a coextensive hollow ring integrally mounted with said coil and having circumferentially spaced apertures therein adapted to direct air under pressure between said coil and said envelope, and means for concurrently energizing said coil and supplying air under pressure to said ring.

4. The method of superheating electrodes within an envelope by induction from an exterior concentric coil carrying high frequency which comprises the step of passing a rapidly moving stream of air between said coil and said envelope.

5. The method of superheating electrodes within an envelope by induction from an exterior concentric coil carrying high frequency which comprises the step of passing a rapidly moving stream of air between said coil and said envelope only when said coil is energized.

6. In the process of heating an electrode contained in an envelope during the exhaust thereof the steps of applying high frequency to induce eddy currents in said electrode to raise its temperature thereby, concurrently supplying a blast of air confined substantially to the surface of said envelope for approximately the same length of time as said high frequency, and delaying the onset and end of said air blast to compensate for the lag in the heating and cooling of said electrode.

7. In the process of heating an electrode contained in an envelope during the exhaust thereof the steps of applying high frequency to induce eddy currents in said electrode to raise its temperature thereby, concurrently supplying a blast of air confined substantially to the surface of said envelope for approximately the same length of time as said high frequency, delaying the onset and end of said air blast to compensate for the lag in the heating and cooling of said electrode, and interlocking the high frequency and air sources to maintain a uniform delay in repeated applications thereof.

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