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MANUFACTURE OF ELECTRON EMISSION TUBES

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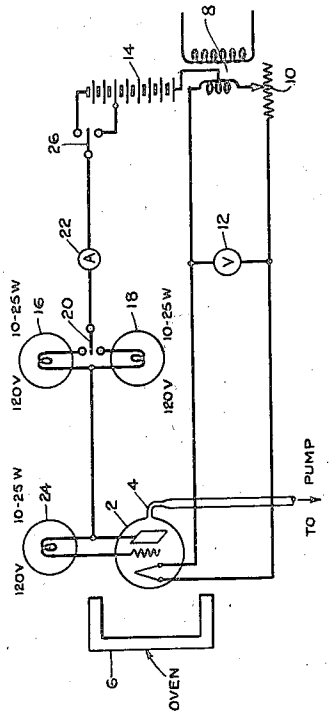



Fig. 1.

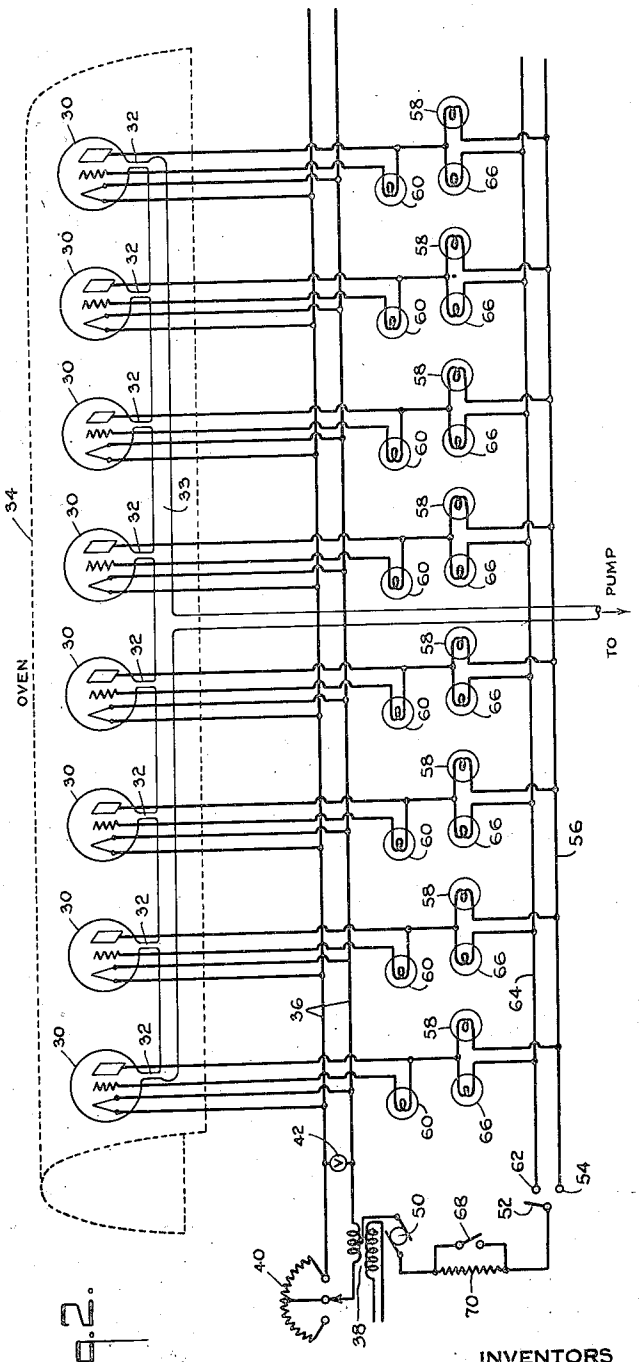



Fig. 2.

INVENTORS
LESTER L. JONES
JOSEPH A. FLANZER
BY
Cavanagh & Jones
ATTORNEYS

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## MANUFACTURE OF ELECTRON EMISSION TUBES

Lester L. Jones, Oradell, N. J., and Joseph A. Flanzer, Brooklyn, N. Y., assignors to Technidyne Corporation, New York, N. Y., a corporation of New York

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10 Claims. (Cl. 250—27.5)

This invention relates to the manufacture of electron emission tubes, and more particularly to the manufacture of tubes in which the electron space current is derived from a heated cathode of the oxide coated type.

In the prior art of manufacturing electron tubes having oxide coated cathodes it has been found that even though the tubes are mechanically similar and undergo identical manufacturing processes large variations are found in the performance of the resulting tubes. These variations are of the order of 25% or more, which constitutes an undesirable lack of uniformity in the product. It has also been found that in accordance with the prior art processes some of the tubes have a long life, others a medium life, and others a very short life, as for example, experiencing a deterioration to 50% of normal performance in a period of from 10 to 30 hours.

The primary object of the present invention is to provide a manufacturing process which will result in electron emission tubes which will give uniform performance as between tubes mechanically similar and similarly processed. A further object of our invention is to produce electron emission tubes having constant performance over a long period of life.

We fulfill the foregoing objects by incorporating in the manufacture of electron emission tubes a cathode activation stage similar in some respects to the reactivation method disclosed in a copending application of the inventors herein and Emil Reisman, Ser. No. 403,218, filed October 29, 1929. In the present process, however, the cathode is activated during the manufacture of the tube and while the tube is being evacuated.

Ordinarily, after the tubes have been preliminarily heated and evacuated for a considerable period of time the tube elements are heated to a still higher temperature for a relatively short period of time by induction from an external coil energized by high frequency current, a step which is commonly called external bombardment. The apparatus for this is cumbersome and of such a nature that it is customary to remove the heating oven from the rack of tubes during bombardment, and to bombard only one tube of the rack of tubes at a time.

This leads to two important disadvantages. In the first place the total time for the manufacture of a rack of tubes is greatly increased over what it would be if all of the tubes in the rack of tubes could be bombarded at once. In the second place, the oven being removed from the rack of tubes during the bombardment, only the first tube of the rack is still real hot when the bombarding step is applied, while the glass envelope of the remaining tubes may, when cool, absorb or occlude gas, so that the tubes from a single rack are non-uniform, and the last tubes thereof are very likely to be "gassy". Accordingly, further objects of our invention are to shorten the time needed for the manufacture of a bank of tubes, and to insure that the bank of tubes will be uniform, and to this end we employ internal rather than external bombardment, so that all of the tubes in the rack may be simultaneously bombarded. This shortens the time of pumping because the greatest time is needed for pumping when the pressure is reduced nearly to a vacuum. This long pumping period only occurs once for an entire rack of tubes in our process, instead of as many times as there are tubes.

Another object of our invention is to devise a process for the accomplishment of the foregoing objects which will necessitate a relatively small investment in production machinery, and which may be economically practiced, so that tubes may be produced at a low cost. The activation step previously mentioned includes a high internal bombardment, and this bombardment may be substituted for the external bombardment ordinarily used, so that by the practice of the present invention external bombardment may be dispensed with, and activation and bombardment obtained together. This does away with the necessity for high frequency bombarding equipment. Economy is also provided in the lesser number of evacuating pumps needed for a given tube output, and in the lower percentage of rejects and seconds in the tubes.

The usual method of manufacturing electron emission tubes may be summarized as follows, the prior art method being divided into numbered steps for the purpose of intimate comparison with our method to be subsequently described in greater detail.

(1) The mechanically assembled tubes are placed on the manifold of an evacuation pump and an oven is placed around the rack of tubes.

(2) The tubes are heated to a temperature of approximately 400 degrees C. and are simultaneously evacuated, the heating and evacuation continuing for about five minutes.

(3) The temperature of the cathode is slowly raised by energizing the heater in order to decompose the carbonates with the evolution of carbon dioxide. The glass and metal ware being hot to not absorb any appreciable amount of the evolved carbon dioxide. The cathode is prefer-

ably heated below normal and the external heating and evacuation continued for about five minutes.

(4) The cathode is further energized until heated to a temperature about as high as or even somewhat higher than the normal operating temperature while continuing the external heating and evacuation of the tubes for a period of about another five minutes.

(5) The oven is then removed from the bank of tubes and bombardment of the tubes is begun. The tubes are externally bombarded one at a time by induction from a high frequency coil placed around the tube. Gas is evolved and the bombardment and evacuation is continued until the gas evolved is pumped out, which may take about two minutes.

(6) After each tube is bombarded the induction coil is lowered over that tube to heat up the cap containing the getter, ordinarily magnesium, which is vaporized and deposited on the walls of the tube and serves to absorb residual gas.

(7) The tube is then sealed off, thereby terminating the evacuation thereof.

The above process is relatively lengthy and complicated and does not lend itself readily to the use of automatic machinery. Furthermore, the tubes resulting from the process have deficiencies in the way of non-uniformity and irregular life. Considered more closely, one of the primary troubles causing both an increase in the time required to pump a given number of tubes, and non-uniformity of treatment of the tubes is the following: It is customary to provide each pump with a manifold so that each pump can evacuate from 8 to 10 tubes simultaneously. Usually two pumps are set side by side with only one induction coil heater or external bombarder, so that one operator can take care of two pumps. This is done because there is nothing for the operator to do after putting a new set of tubes on one pump until these tubes have been heated by the oven, which, as explained above, takes about 10 minutes. If only one pump position were available the operator would only have a few minutes work preparing the next set of tubes for insertion into the pump. Also, there is danger to the operator if an external bombarder is working on a rack of tubes while the operator is sealing off and removing a tube from that rack. So the preferred procedure is to have the operator bombard a tube in one rack while sealing off a previously bombarded tube in the other rack.

It can be seen from the above that each tube in the manifold undergoes a different length of pumping and experiences a different gas history. The first tube to be removed is pumped for the shortest time, and the remaining tubes undergo longer pumping. Furthermore, the latter tubes are exposed to a progressively increasing after dosage or reintroduction of gas after evacuation, with accompanying uncertain and injurious results, due to gas liberated during bombardment of the preceding tubes in the same rack.

Further objects of our invention are to overcome the foregoing difficulties of the above process, as well as to economically produce tubes which are uniform in performance, and which have long life with high and constant efficiency, especially with respect to those factors which depend upon the supply of an adequate stream of electrons at moderate cathode temperatures.

To the accomplishment of the foregoing and such other objects as will hereinafter appear, our invention consists in the elements and their relation one to the other as hereinafter are more particularly described in the specification and sought to be defined in the claims. The specification is accompanied by drawing in which:

Fig. 1 is a schematic wiring diagram explanatory of the practice of our invention; and

Fig. 2 shows the application of our invention to a rack of tubes.

Our process is generally similar in respect to steps 1 through 4 of the foregoing outline of present practice in manufacturing tubes, but is markedly different with respect to step 5. This step in the prior art is simply an external bombardment intended to evolve gas from the metallic electrodes, which gas is pumped from the tubes. We instead at this point arrange to activate the tube cathode, which we do essentially by increasing the cathode temperature substantially above normal, say by applying 50% excess cathode heater terminal potential, and applying a high positive anode potential. The anode potential may be applied for approximately one minute and the resulting space current is preferably held within a desired limit dependent upon the radiating surface of the bombarded electrodes. This limit should be smaller during the first portion of the activating step but may be increased during the later portion of the activation stage. In the first portion there may be gas in the tube which if ionized will cause considerable space current to flow, whereas this gas will have been substantially evacuated during the second portion, and also, the cathode material is itself improved during the activation, and for these two reasons we find that the space current limit should preferably be different during the first and second portions of the activation stage.

Heating of the electrodes being bombarded is desired, but it is not desirable to have excessive electron flow which might injure the cathode. The heat generated depends upon the power dissipated, or the product of the current and the potential. The current should be small in order not to injure the cathode, and it is therefore necessary to have a high potential. At the same time, if the tube has a grid the latter may be injured by excessive heating because of its low radiating ability, and it is therefore desirable to limit the heating of the grid relative to the heating of the anode. Both of these requirements may be fulfilled by increasing the potential applied to the anode, and applying a reduced potential to the grid relative to that applied to the anode, thereby increasing the tube impedance and decreasing the electron flow while increasing the anode potential. The reduced potential of the grid relative to that of the anode proportions the distribution of the heat liberated in the grid and in the anode, so that the grid is not excessively heated.

But equally important, the total space current must be additionally controlled so as to prevent overheating of both the grid and the anode, which ordinarily contain nickel, for overheating of the bombarded electrodes results in the vaporization of the nickel therein. This may be detected by a dark deposit of nickel on the relatively while oxide coated cathode of the tube, and also by a darkening of the tube envelope due to a deposit of nickel on the inside wall thereof. Nickel vapor poisons the cathode and prevents emission, so that it is necessary to prevent the vaporization of nickel, even though the bombardment is not sufficiently great to actually visibly destroy the bombarded electrodes.

The cathode may also contain nickel, particularly in the heater type tubes, which usually use a nickel sleeve. Heat radiated from the bombarded grid and anode is added to the normal cathode heat, and this may cause the release of nickel vapor from the cathode itself with injurious effects similar to those previously noted.

The theory behind the activation step is not certain, but possibly is explained as follows. During the high internal bombardment which we apply to the tube gas in the tube is ionized by the electron stream from the cathode, and the positive ions thereof bombard the cathode and hit it with a high velocity and probably form a layer of positive ions on the surface which acts to reduce the space charge at the surface, so that the electron stream may readily flow out of the cathode. Also, in the latter part of the activation step the high electron current builds up a supply of the metal barium by electrolytic formation, which makes an improved electron emitter. Some barium is formed in the cathode when tubes are manufactured by the prior process previously described. This supply of barium may be maintained, but more likely is gradually diminished during the use of the tube, the rate of formation of barium during normal use being less than the rate of exhaustion thereof. In our process the activation step probably forms a larger initial supply of barium, sufficient to make up for a gradual loss of barium over a long period of time. Also, a good supply of barium to begin with causes improved cathode emission, which probably helps cause a faster rate of formation of barium during normal use, so that the barium supply is more likely to be kept up to full value during the use of the tube.

When a tube which is already sealed off is being activated or reactivated in accordance with the copending application already referred to a problem arises to get rid of the resulting gas. By flickering or shutting off the anode and grid potentials momentarily the gas molecules go to the glass and somewhat to the anode, but do not go back into the cathode because the cathode is still heated. Molecular or deionized gas is free, and it is only during flickering of the anode potential and while the anode voltage is stopped that the gas ions may reform into molecules and go to the glass. During the manufacturing step with which we are here dealing the problem is different and more simple of solution because the evacuation of the tube is being continued and the gas is extracted in that manner. Flickering therefore need not be employed, but nevertheless is desirable because by its use the pumping operation may be considerably shortened, for deionized or molecular gas is freed of ionization forces and is more easily removed by the pump. Therefore, during the activation step previously described the space current may be flickered by occasionally momentarily interrupting the anode and grid potentials while continuing the evacuation of the tube envelope.

Our process for the manufacture of electron emission tubes may be more completely described as follows, the process being divided into seven steps in order to simplify comparison between this process and the prior art process previously outlined.

(1) The mechanically assembled tubes are placed on the manifold of an evacuation pump and an oven is placed around the rack of tubes.

(2) The tubes are heated to a temperature of approximately 400 degrees C. and are simultaneously evacuated, the heating and evacuation continuing for about five minutes.

(3) The temperature of the cathode is slowly raised by energizing the heater in order to decompose the carbonates with the evolution of carbon dioxide. The glass and metal ware being hot do not absorb any appreciable amount of the evolved carbon dioxide. The cathode is preferably heated below normal and the external heating and evacuation continued for about five minutes.

(4) The cathode is further energized until heated to a temperature about as high as or even somewhat higher than the normal operating temperature while continuing the external heating and evacuation of the tubes for a period of about another five minutes.

(5) The cathode temperature is next increased by an amount corresponding to an increase of approximately 50% above normal in the heater voltage. A high positive voltage is applied to the anode for a period of approximately one minute, which causes electronic bombardment and heating of the plate to a high temperature. This internal bombardment is further considered under sub-headings 5A, 5B, and 5C below.

(5A) In the first period of the bombardment stage care should be taken to control the space current and to hold it down to a small value, such as, for example, 100MA per square centimeter of cathode area. This is important because without limitation the current might rise to very high values due to gas ionization in the initial stage of electronic bombardment. After approximately ½ minute enough gas will have been pumped out to prevent such current overloads.

(5B) After the gas pressure is reduced below the value where heavy ionization can take place the current limitation may be raised to approximately 250MA per square centimeter of cathode area for the remainder or second half minute of the bombardment stage. This current limitation causes a red heat on the plate without raising the plate to such a high temperature as will cause vaporization thereof. If the anode is made of a metal such as molybdenum or tungsten the current limitation may be increased to 300 or 400MA per square centimeter of cathode area without vaporization of the metal. These current values are for vacuum tubes having anodes with approximately 4 square centimeters of radiating surface for about one square centimeter of cathode area. Current values proportional to the anode areas may be used for other tubes.

(5C) The anode potential should preferably but only optionally be interrupted for periods of one or two seconds during the bombardment stage 5, or periods 5A and 5B preceding, to permit deionization. When the process is being applied to a tube having a grid the anode potential interruption should be accompanied by a simultaneous grid potential interruption.

(6) The getter is then flashed either by induction from a high frequency coil, or more preferably by raising the plate temperature so as to heat the getter to the vaporization point. This increase in plate temperature may be obtained automatically, or by raising the anode potential. It is not injurious because it lasts for only a very short interval of time, say a few seconds, and by its use external bombardment and the apparatus therefor may be entirely dispensed with. On the other hand, if it is desired to use external bombardment the disadvantages previously pointed out when external bombardment is used for step 5 are not present here for the reason that only

a few seconds are needed to flash the getter, so that the entire rack of tubes may be put through this step in very short order. When flashing the getter automatically advantage is taken of the fact that the anode temperature rises as the vacuum in the tube is made more perfect, due to the reduction of heat conduction away from the anode, and this rise in temperature flashes the getter. Such automatic flashing insures that the getter will not be flashed prematurely, that is, before the vacuum is sufficiently perfect to prevent exhaustion of the getter by absorption of gas improperly left in the tube by insufficient evacuation.

(7) The tube is then sealed off, thereby terminating the evacuation thereof.

In order to conveniently control the space current during the internal bombardment (step 5) a current limiting device having a high positive temperature coefficient of resistance should be inserted in the plate supply lead. A suitable device of this character is an ordinary tungsten incandescent lamp. With tubes having one square centimeter cathode area a 25 watt, 120 volt lamp is suitable for the first period (step 5A) when the gas content is fairly high, and a 100 watt, 120 volt lamp is suitable for the second period (step 5B) when the gas content is quite low. The different resistances are employed in order to obtain the desired different values of space current previously discussed under steps 5A and 5B supra. Each of the resistances is characterized by a high positive temperature coefficient in order to obtain automatic regulation of the space current in each of the periods to the value desired during that period.

In applying our method to a vacuum tube having a grid the current taken by the grid should be controlled so that the grid is not overheated. The voltage of the grid must be predetermined so as to create proper zones of ionization, which feature we believe, relates to securing suitable though not excessive high velocity positive ion bombardment of the cathode. It is also necessary to control the grid voltage so as to secure a suitable tube impedance and space current, as well as to distribute the grid and plate heat. At the very beginning of the bombardment period the grid voltage must be high so as to get the electron current to flow in appreciable quantity, whereas during the remainder of the bombardment, after the emission has been fairly well established, the grid voltage should be reduced to prevent overheating of the grid.

In order to secure a suitable control of the grid voltage during this bombardment we have found that it is sufficient to connect the grid to the anode through a resistance having a high positive temperature coefficient of resistance such as a tungsten filament incandescent lamp. A resistance connected between the grid and the plate causes a lower potential to be applied to the grid than to the plate because of the voltage drop across the resistance. This drop is zero when no grid current flows, and therefore the initial grid potential applied is high, but when grid current begins to flow the grid potential is reduced, and if excessive grid current flows the potential is further reduced, which tends to regulate the grid current. The use of a resistance having a high positive temperature coefficient rather than a simple resistance is desirable in order to permit the cathode current to get well started before the grid potential is reduced. In our arrangement the reduction in grid potential is delayed by the time needed to heat up the resistance, and this delay helps the cathode emission get under way. From another viewpoint we may say that the resistance, if not characterized by a high positive temperature coefficient, would have to be a much higher resistance than the cold resistance of the tungsten lamp, and this high resistance would operate to quickly reduce the grid potential the instant the cathode emission started. With tubes such as those described above and having amplification constants of the order of 12, we have found that a 120 volt tungsten lamp rating anywhere between 10 and 25 watts is suitable for creating the automatic control of the grid voltage.

Referring to Fig. 1 of the drawing the tube to be evacuated is indicated at 2 and the stem 4 thereof is connected to a vacuum pump in the usual manner. An oven 6 is used to heat the tube during the entire process if no external bombardment is employed, or is used through steps 1 through 5 if a brief external bombardment is employed in step 6. During the activation process described in step 5 the cathode of the tube is heated from a suitable source of current, say the transformer 8, the cathode potential being varied by a resistor 10 and measured by a volt meter 12. The anode is polarized by a source of direct potential such as the battery 14, the anode potential being applied to the tube anode through either a 25 watt lamp 16 or a 100 watt lamp 18 according as the switch 20 is thrown upward or downward. These lamps serve to limit the space current during the activation process, lamp 16 being used during the first portion, and lamp 18 being used during the second portion of the activation stage. A milli-ammeter 22 may be included in circuit to check up on the value of the space current. Switch 20 may also be used for flickering. A lamp 24 is connected between the anode and control electrode of the tube in the case of a three electrode tube in order to automatically regulate the grid potential, as was previously described. Switch 26 may be temporarily thrown from the low potential to the high potential contact for flashing the getter, if neither external nor automatic flashing is used.

Our invention is of especial manufacturing advantage because it then is applied to a rack of tubes rather than to a single tube. Such an arrangement is schematically illustrated in Fig. 2 in which a rack of tubes 30 are mounted on a pump, the stems 32 of the tubes being connected to a manifold 33 on the pump. The rack of tubes is surrounded by an oven the hood 34 of which is indicated in dotted lines. In this manner the tubes may be heated and evacuated at one time.

The cathodes of each of the tubes 30 are connected to bus bars 36, to which cathode heating current is supplied from a source 38 through a potential varying rheostat 40, the potential being observed on a voltmeter 42. The rheostat 40 is cut out of circuit so as to raise the cathode temperature during the evacuation process, this temperature being preferably gradually raised, for example, in three stages corresponding to steps 3, 4, and 5 above, the cathode temperature being somewhat below normal during step 3, and about at normal or slightly above normal during step 4, and increased to a substantial amount above normal during step 5, the bombardment stage. In the case of heater type tubes the heater may be connected in circuit as shown, but the negative terminal of the source 50 is connected to the cathode emitter itself. With heater type tubes direct current as

from a battery may be used to heat the cathode, the transformer being especially preferred for directly heated cathodes because during reactivation the plate current is very high, and without the equalization permitted by the center tap and the use of alternating current the cathode would be very unequally heated along its length.

The bombardment is applied simultaneously to all of the tubes in the rack, and is internal, the cathode temperature being raised substantially above normal, say to a temperature resulting from the application of a cathode heater potential 50% in excess of the normal potential, and at the same time applying a high positive potential to the anodes of the tubes. This bombardment may extend over a period of say one minute which may be divided into two periods of say a half minute each. The anode potential is supplied from a power line or generator 50, switch 68 being open, and is applied to the tube anodes by closing the switch 52 onto the contact 54. The potential applied to the bus 56 is led to each of the anodes through individual ballast lamps 58, corresponding to the 25 watt lamp in Fig. 1. At the same time the control electrodes of each of the tubes is connected with the anode of each of the tubes through separate lamps 60, which serve to regulate the grid potential relative to the anode potential. Reduction in grid potential after the cathode emission gets started increases the impedance of the tube and thereby decreases the electron emission from the cathode, so that a high anode potential may be used in order to get high impact velocity of the electrons on the anode and consequent heating thereof. Meanwhile, the current to the grid relative to that to the anode is reduced, so that overheating of the grid is prevented. The total grid and anode space current flow is regulated and limited by the lamps 58, in order to prevent excessive electron emission from the cathode in the event of ionization.

During the second half minute of the bombardment the switch 52 is closed onto contact 62, so that the anode potential is applied to the tubes through bus 64 and lamps 66, which correspond to the 100 watt lamp 18 in Fig. 1. This permits a larger space current to flow during the latter half of the bombardment. Lamps 66, however, regulate and limit this larger current in order to prevent overheating and vaporization of the anode. During the entire bombardment stage the switch 52 may occasionally be momentarily opened in order to flicker the anode potential, which facilitates the evacuation of the tubes in the manner previously explained. The getter may be flashed automatically by taking advantage of the rise in anode potential which takes place when the vacuum in the tube becomes very nearly perfect. Such automatic flashing of the getter is desirable in order to prevent premature flashing of the getter and consequent exhaustion thereof. If desired, the getter may be flashed by raising the anode potential, which may be accomplished in the present arrangement by closing the switch 68 in order to short circuit the series resistance 70. The resulting rise in anode potential is not injurious to the tube because it is permitted to exist for only the few seconds needed to flash the getter.

While we have described our invention as being particularly advantageous because of the elimination of external bombardment, it should be appreciated that in one aspect an important feature of our invention resides in the inclusion in tube manufacture of cathode activation during the evacuation of the tube. This is mentioned becaused when dealing with a large tube having relatively heavy metal parts it may be desired to aid the internal bombardment with external bombardment, in which case the internal bombardment, though only partial, is extremely valuable because of the resulting activation of the tube cathode.

With our arrangement every manufacturing step which the tube undergoes is applied identically to all of the tubes in the rack and the entire manufacturing process for a rack of tubes takes practically only as long as the manufacture of a single tube would take. Meanwhile, such factors as should be applied to the tubes individually owing to possible differences in their characteristics, such as cathode emission, are taken care of by the use of individual ballasting or current limiting and potential regulating lamps such as the lamps 58, 60, and 66. The bombardment is applied to the tubes while the tubes are all hot and there is no tendency for gas to occlude on the walls of the tube. Better still, the bombardment may and preferably is applied to the tubes while the tubes are still being heated by the oven, which makes it still easier to obtain the desired temperatures and to prevent occlusion of gas. The time of pumping of the entire bank of tubes is about as long as the time of pumping only the first tube of the rack of tubes by the old method, for the preliminary evacuation before bombardment is the same in each case, while the evacuation after bombardment is but little, if at all longer, for the reason that pumping when there is substantial gas pressure proceeds very rapidly, while evacuation when a vacuum is nearly approached is relatively slow. With our process the entire bank of tubes is simultaneously bombarded and considerable gas is released, so that the preliminary evacuation proceeds very rapidly. The lengthy evacuation needed when a vacuum is nearly approached is the same as when a single tube has been bombarded, for even when only a single tube is bombarded the entire rack of tubes must be brought down to the desired vacuum before the said single tube may be sealed off.

Our process leads to uniformity when many tubes are put on a manifold connected to one pump, primarily because the tubes liberate gas from their metal parts simultaneously instead of successively. The internal bombardment employed in our process during the activation step in this respect differs completely from external bombardment by means of a high frequency induction coil. Instead of bringing the whole manifold down to minimum pressure many times in succession, each taking a long time, we bring the manifold down to minimum pressure only once. All of the tubes on one manifold get the same gas treatment, with no injurious after dosage due to gas liberated from a tube being bombarded traveling back through the manifold to the remaining tubes.

We have also found that tubes manufactured in accordance with our process have a remarkable degree of uniformity and long life. This we attribute to the inclusion in the process of the activation process described in the copending application aforementioned.

It will be apparent that while we have shown and described our process in preferred form, many changes and modifications may be made therein without departing from the spirit of the invention, defined in the following claims.

We claim:

1. In the manufacture of electron emission tubes having an oxide coated cathode, the method which includes heating and evacuating the tube for a substantial period of time, say five minutes, energizing the cathode and thereby raising the cathode temperature to approximately its normal operating temperature while continuing the heating and evacuation of the tube, for a longer period of time, say ten minutes, and then activating the cathode by both increasing the cathode temperature substantially above normal and applying a high positive anode potential immediately thereafter for a shorter period of time, say one minute, in order to bombard and activate the tube while the tube is still hot and while continuing the evacuation of the tube.

2. In the manufacture of electron emission tubes having an oxide coated cathode, the method which includes heating and evacuating the tube for about five minutes, energizing the cathode and thereby raising the cathode temperature in stages to approximately its normal operating temperature while continuing the heating and evacuation of the tube for about ten minutes, and then activating the cathode by both increasing the cathode temperature substantially above normal and applying a high positive anode potential for about one minute in order to bombard and activate the tube while the tube is still hot and while continuing the evacuation of the tube.

3. In the manufacture of electron emission tubes having an oxide coated cathode and a grid, the method which includes heating and evacuating the tube for a substantial period of time, say five minutes, energizing the cathode and thereby raising the cathode temperature to approximately the normal operating temperature while continuing the heating and evacuation of the tube for a period of time, say ten minutes, and immediately thereafter activating the cathode by increasing the cathode temperature substantially above normal and applying a high positive potential to the anode and a reduced potential to the grid for a shorter period of time, say one minute, in order to bombard and activate the tube while the tube is still hot and while continuing the evacuation of the tube.

4. In the manufacture of electron emission tubes having an oxide coated cathode and a grid, the method which includes heating and evacuating the tube for about five minutes, energizing the cathode and thereby raising the cathode temperature in stages to approximately the normal operating temperature while continuing the heating and evacuation of the tube for about ten minutes, and activating the cathode and bombarding the tube by increasing the cathode temperature substantially above normal to a temperature corresponding to about a 50% increase in cathode terminal potential, and applying a high positive potential to the anode and a reduced potential to the grid for about one minute while the tube is still hot and while continuing the evacuation of the tube.

5. In the manufacture of electron emission tubes having an oxide coated cathode, the method which includes heating and evacuating the tube for about five minutes, raising the cathode temperature to approximately its normal operating temperature and continuing the heating and evacuation of the tube for about ten minutes, then activating the cathode and bombarding the tube by increasing the cathode temperature substantially above normal and applying a high positive anode potential for approximately one minute, the space current being held within a desired limit dependent upon the radiating surface of the bombarded electrode, still further raising the anode potential in order to flash the getter, and finally stopping evacuation by sealing off the tube.

6. In the manufacture of electron emission tubes having an oxide coated cathode, the method which includes heating and evacuating the tube for about five minutes, raising the cathode temperature to approximately its normal operating temperature and continuing the heating and evacuation of the tube for about ten minutes, bombarding the tube by increasing the cathode temperature substantially above normal and applying a high positive anode potential for approximately one minute, flickering the space current during the bombardment by occasionally interrupting the anode potential for periods of approximately one second, and finally stopping evacuation by sealing off the tube.

7. In the manufacture of electron emission tubes, the method which includes heating the tube at a temperature of approximately 400° C. and simultaneously evacuating the tube envelope for a period of about five minutes, raising the cathode temperature to approximately its normal operating temperature and continuing the heating and evacuation of the tube for about ten minutes, bombarding the tube by increasing the cathode temperature above normal by an amount corresponding to a 50% increase in cathode terminal potential, and applying a high positive anode potential for approximately one minute, the resulting space current being held within a desired limit dependent upon the radiating surface of the anode, flickering the space current during the bombardment by occasionally interrupting the anode potential for periods of approximately one second, still further raising the anode potential in order to flash the getter, and finally stopping evacuation by sealing off the tube.

8. In the manufacture of electron emission tubes having an oxide coated cathode, the method which includes simultaneously heating and evacuating a rack of tubes for about five minutes, raising the cathode temperature of the tubes to approximately the normal operating temperature while continuing the heating and the evacuation of the rack of tubes for about ten minutes, and activating and bombarding all of the tubes in the rack at once while they are still hot and while still evacuating the tubes by increasing the cathode temperature substantially above normal and applying a high positive anode potential for about one minute.

9. In the manufacture of electron emission tubes having an oxide coated cathode and a grid, the method which includes simultaneously heating and evacuating a rack of tubes for a substantial period of time, say five minutes, energizing the cathode and thereby raising the cathode temperature of the tubes to approximately the normal operating temperating while continuing the heating and the evacuation of the rack of tubes, for a longer period of time, say ten minutes activating and bombarding all of the tubes in the rack at once while they are still hot and while still evacuating the tubes by increasing the cathode temperature substantially above normal and applying a high positive potential to the anodes and a reduced potential to the grids of the tubes for a shorter period of time, say one minute.

10. In the manufacture of electron emission

tubes having an oxide coated cathode, the method which includes simultaneously heating and evacuating a rack of tubes, for a substantial period of time, say five minutes, raising the cathode temperature of the tubes to approximately the normal operating temperature while continuing the heating and the evacuation of the rack of tubes, for a longer period of time, say ten minutes, bombarding all of the tubes in the rack at once while they are still hot and while still evacuating the tubes by increasing the cathode temperature substantially above normal and applying a high positive anode potential, for a shorter period of time, say one minute, and flickering the space current during the bombardment by occasionally momentarily interrupting the anode potential.

LESTER L. JONES.
JOSEPH A. FLANZER.