Sept. 19, 1944. W. W. EITEL ET AL 2,358,566

METHOD OF EVACUATING TUBES

Filed Dec. 30, 1942 5 Sheets-Sheet 1

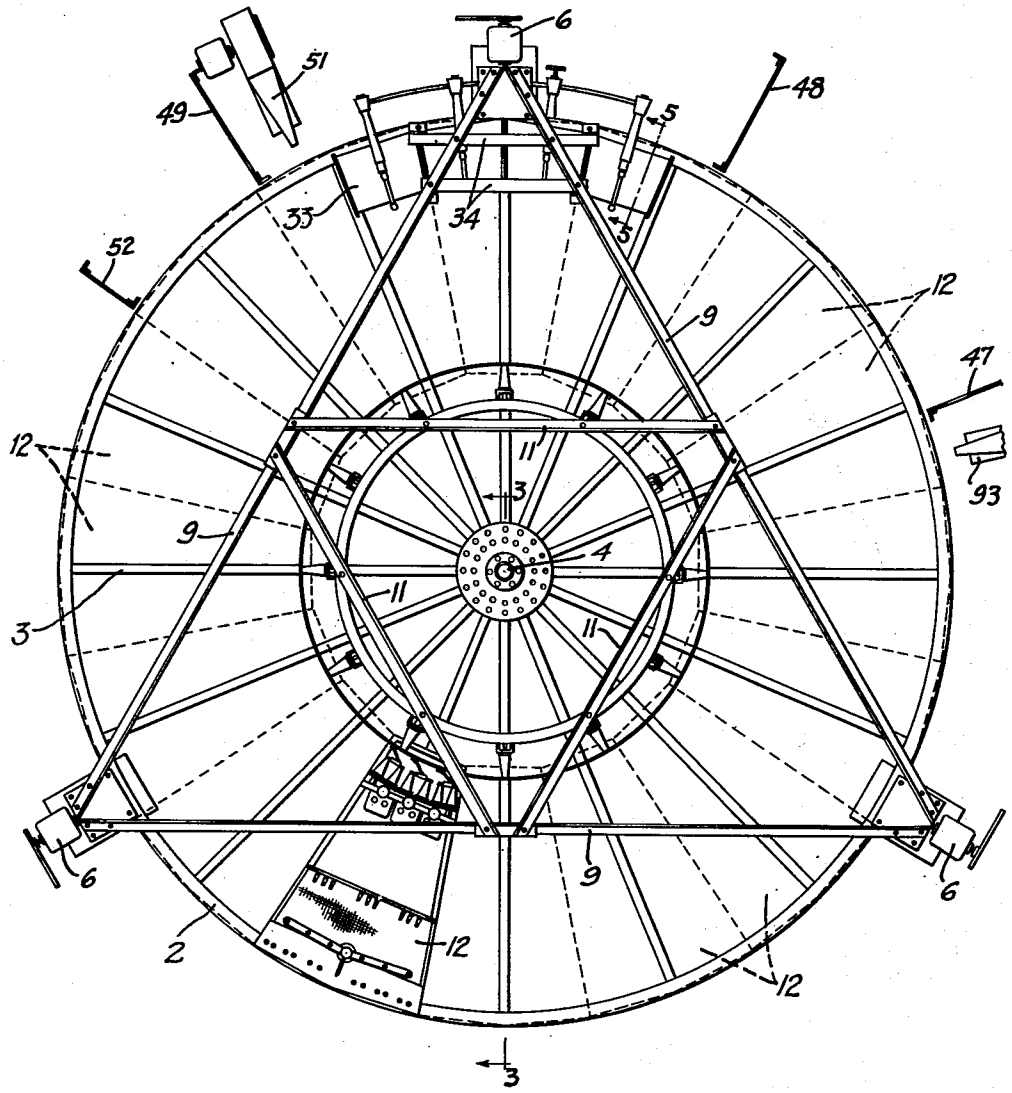


Fig. 1

INVENTORS
WILLIAM W. EITEL
JACK A. Mc CULLOUGH
BY Harold E. Sorg
THEIR ATTORNEY

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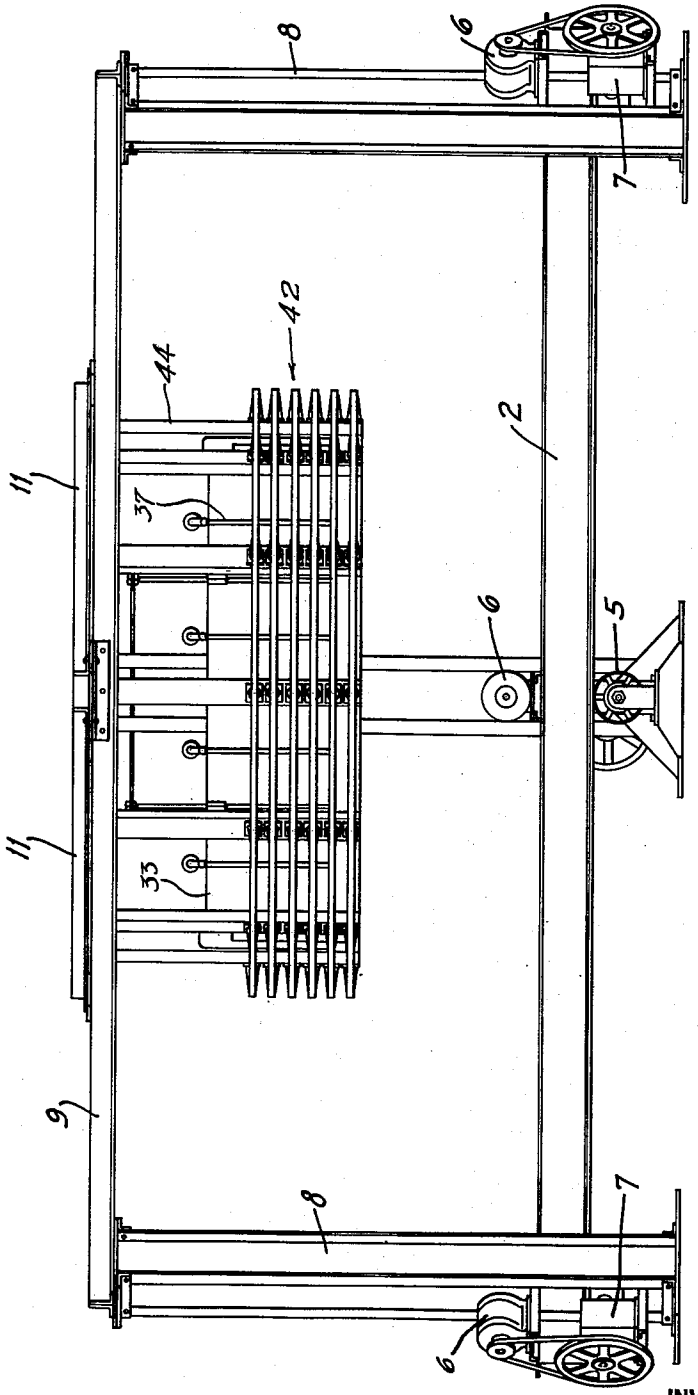


Fig. 2

INVENTORS
WILLIAM W. EITEL
JACK A. McCULLOUGH
BY Harold E. Sarg
THEIR ATTORNEY

Sept. 19, 1944. W. W. EITEL ET AL 2,358,566

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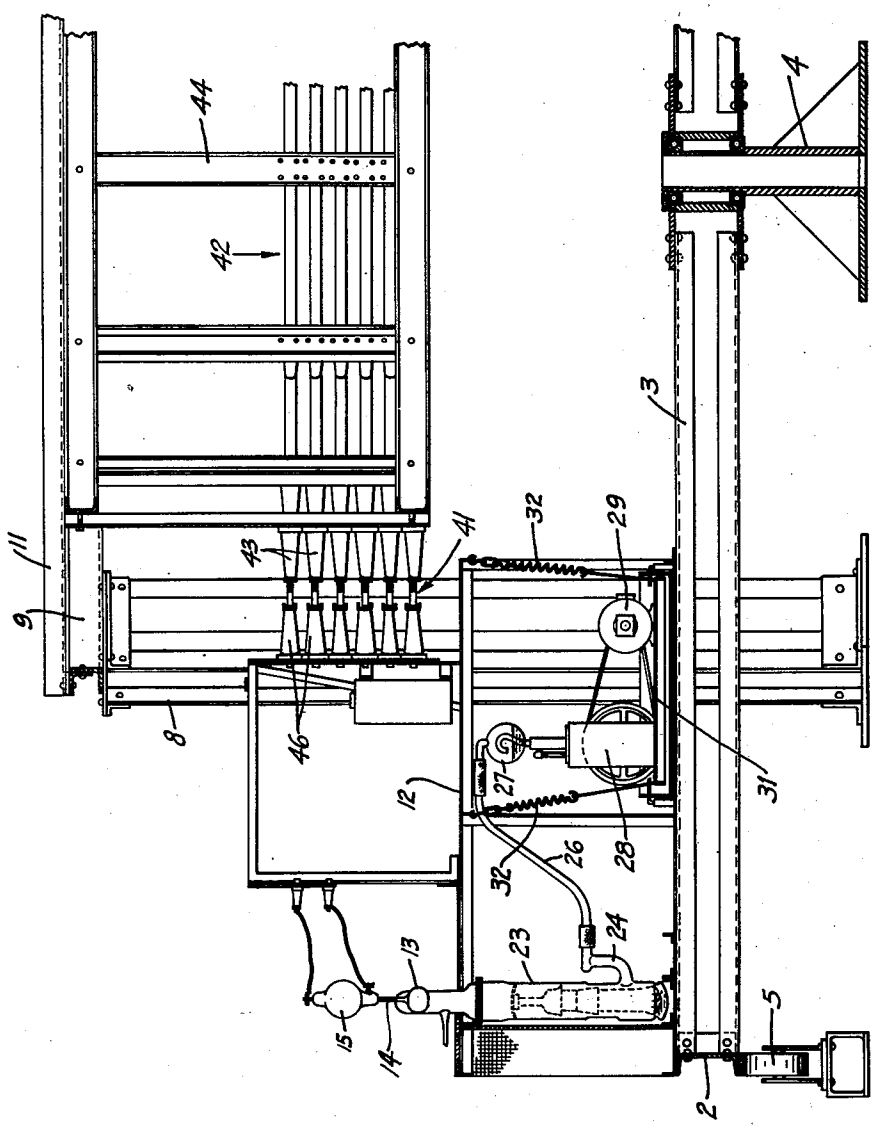


Fig. 3

INVENTORS
WILLIAM W. EITEL
JACK A. Mc CULLOUGH
BY Harold E. Song
THEIR ATTORNEY

Sept. 19, 1944. W. W. EITEL ET AL 2,358,566

METHOD OF EVACUATING TUBES

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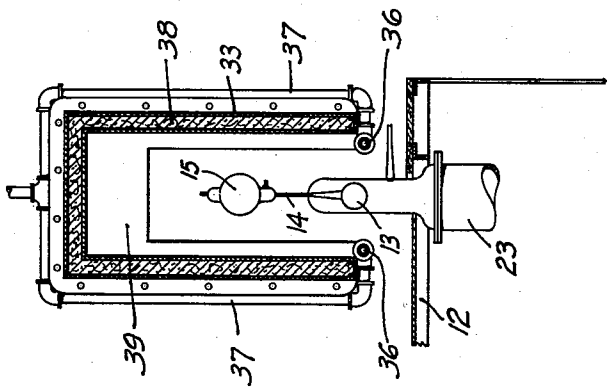


Fig. 5

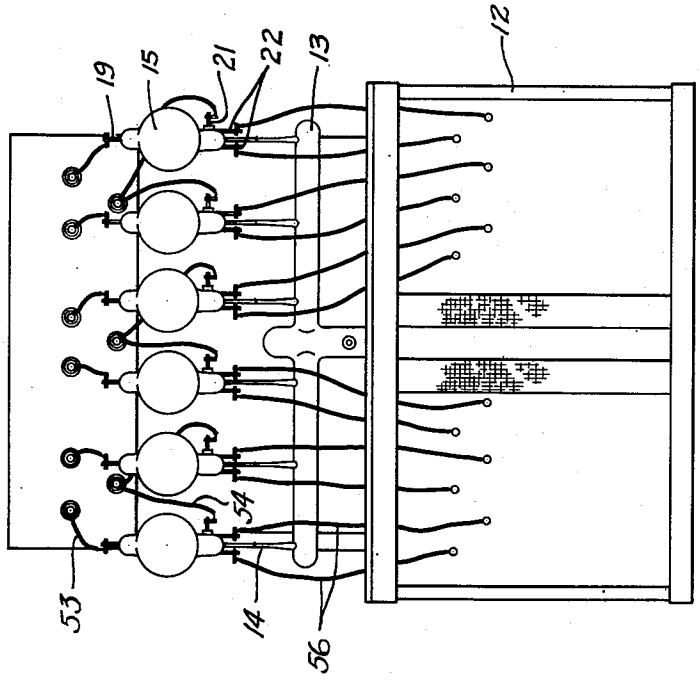


Fig. 4

INVENTORS
WILLIAM W. EITEL
JACK A. McCULLOUGH
BY Harold E. Ing
THEIR ATTORNEY

Sept. 19, 1944. W. W. EITEL ET AL 2,358,566

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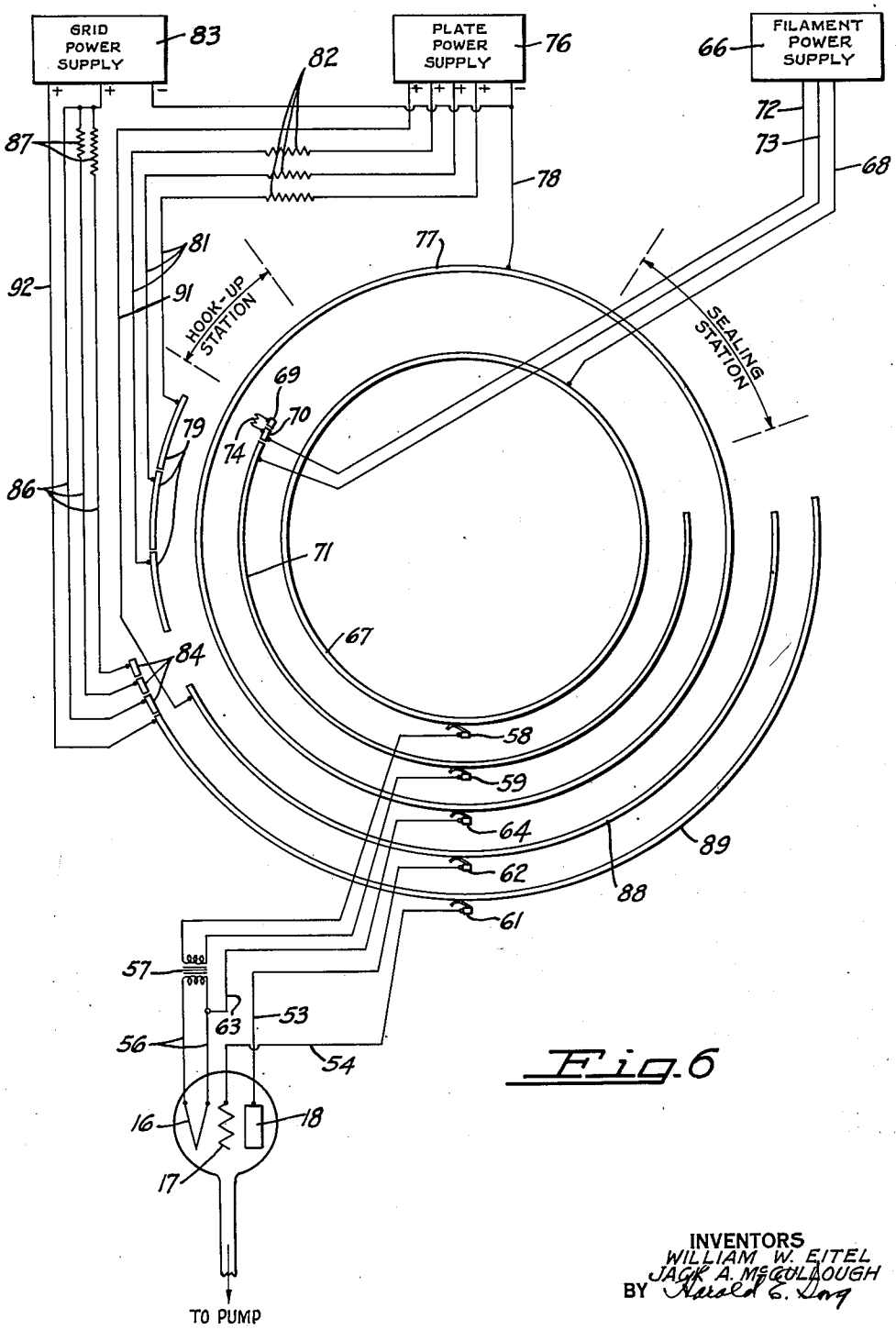


Fig. 6

INVENTORS
WILLIAM W. EITEL
JACK A. McCULLOUGH
BY Harold E. Dorg

THEIR ATTORNEY

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UNITED STATES PATENT OFFICE

2,358,566

METHOD OF EVACUATING TUBES

William W. Eitel, San Bruno, and Jack A. McCullough, Millbrae, Calif., assignors to Eitel-McCullough, Inc., San Bruno, Calif., a corporation of California

Application December 30, 1942, Serial No. 470,676

6 Claims. (Cl. 316—26)

Our invention relates to the manufacture of vacuum tubes such as electron tubes having an envelope enclosing a plurality of electrodes.

It is among the objects of our invention to simplify and facilitate the evacuation of electron tubes.

Another object is to improve the quality of the products by eliminating the human equation during the exhaust procedure, whereby a greater degree of uniformity is attained between tubes.

A further object is to provide an improved method of exhausting tubes, embodying the principle of electronically bombarding electrodes to heat the same for driving out occluded gases during the exhaust.

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 drawings:

Figure 1 is a plan view of apparatus embodying the improvements of our invention, all of the carriages except one on the rotatable frame being merely indicated by dotted lines to simplify the view.

Figure 2 is a side elevational view of the frame, the carriages being omitted to show the central buss bar structure.

Figure 3 is a fragmentary vertical sectional view, taken in a plane indicated by lines 3—3 of Figure 1, one of the carriages being included in full lines in this section.

Figure 4 is a detail elevational view looking at the front of one of the carriages.

Figure 5 is a detail sectional view of the oven, taken in a plane indicated by line 5—5 of Figure 1.

Figure 6 is a diagrammatic view showing the various connections to the buss bars.

In terms of broad inclusion, our method of evacuating a tube comprises moving it along a path, and, while the tube is in motion, exhausting it and simultaneously heating an electrode therein to outgas it. With tubes having a cathode and other electrodes, such as a plate and grid, the other electrodes are preferably heated by electron bombardment from the cathode. The bombardment is controlled to heat selected electrodes during predetermined periods of the tube movement, in accordance with a prearranged exhaust schedule. With this method the tubes are evacuated by a continuous exhaust process, new tubes being introduced at one point along the path and the completed tubes being removed at another point. Our preferred apparatus for carrying out the improved method comprises a movable frame for holding the tubes; means on the frame for exhausting the tubes; means for heating the tube envelopes; means for energizing the cathodes; and means timed with the frame movement for applying positive potentials to other electrodes for bombarding them with electrons from the cathodes during predetermined periods of the tube travel.

In greater detail, the improvements embodying our invention will be described by first considering the apparatus and then discussing its mode of operation. The novel methods involved will become clear as the description progresses.

Apparatus

Referring to the drawings, our apparatus comprises a rotatable frame or wheel having a rim 2 with spokes 3 terminating at a hub journaled about a vertical axis on a centrally disposed standard 4. The periphery of the wheel is additionally supported by rollers 5 under rim 2, several of these rollers being positively driven by motors 6 through reduction gearings 7 to impart motion to the wheel. The rotatable frame or wheel is driven at a slow rate, depending upon the time required to complete the exhaust of a tube. For purposes of illustration we will take a four hour cycle, which means that the wheel will make one complete revolution in four hours. Fixed parts of the apparatus are supported by a main frame comprising pillars 8 carrying a superstructure composed of triangularly arranged beams 9 and cross beams 11.

Means are provided on the rotatable frame for carrying the tubes to be exhausted and the associated pumping equipment. For this purpose, as shown in Figure 1, there are a plurality of say sixteen pie-shaped carriages 12 arranged on the wheel. These carriages fit side-by-side and together form a circle coextensive with the wheel. Referring to Figures 3 and 4, each carriage has a glass manifold 13 to which exhaust tubulations 14 of tubes 15 are sealed. Six tubes are shown on a manifold, but this may be varied depending upon the size of tube and capacity of the pump. With sixteen carriages carrying six tubes each, that makes a total of ninety-six tubes, it being understood of course that completed tubes are constantly being removed and

replaced with new ones so that the process is a continuous one. The tubes shown, which are merely for purposes of illustration, are triodes comprising a glass envelope enclosing a filamentary cathode 16, a grid 17 and a plate 18. See the diagrammatic representation of a tube in Figure 6. The tubes illustrated in Figure 4 have a plate lead 19 out the top, a grid lead 21 out the side, and cathode leads 22 out the bottom of the envelope. Here again the specific arrangement of the leads will vary with different tube types. If the tube is one having a base the latter is applied after exhaust, as will be understood by those skilled in the art.

In order to facilitate servicing and repair, the individual carriages 12 are removably mounted on the rotatable frame, so that a carriage may be taken off and replaced with another without holding up operation of the machine as a whole. As shown in Figure 3 a carriage rests on rim 2 and also on a spoke 3 of the wheel, thereby giving adequate support yet allowing a given carriage to be slidably withdrawn from its nested position between adjacent carriages. The pie-shape of the carriages facilitates this withdrawal.

Means are provided on the carriages for evacuating the tubes on manifolds 13. With reference to Figure 3, a vacuum pump 23, preferably of the oil diffusion type, is arranged on each carriage below manifold 13 and directly connected therewith. Arm 24 on the low pressure side of this pump is connected by a hose 26 through an oil trap 27 to a backing pump 28 which may be of a suitable mechanical type driven by a motor 29. In order to damp vibration of the mechanical pump the latter together with its motor is mounted on a plate 31 suspended in the carriage by springs 32. By this arrangement a self-contained pump unit is provided on each carriage, operating independently of the other carriages. This gives adequate pumping capacity for the tubes on a given manifold, and, should a pumping unit fail, only those tubes on that carriage are affected. Withdrawal of the carriage removes the entire pumping unit for replacement or repair. An important feature of the improved apparatus, here to be noted, is that the vacuum pump travels with the tube. This eliminates any need for rotating joints or the like in the vacuum connections, which joints are practically impossible to keep vacuum tight. In our apparatus there is a positive direct connection between the tube and pump.

Means are provided for heating the tubes during a portion of their travel on the rotating wheel. This heating is for the purpose of driving occluded gas out of the glass envelopes. As shown in Figures 1 and 5, an arcuately shaped tunnel-like oven 33 is arranged along the circular path taken by the tubes. The oven is open at the ends and at the bottom so that the tubes on the manifold are able to pass through. This heating unit is suspended in fixed position from straps 34 on beams 9 of the main frame. The oven is fired by gas burners 36 arranged along the lower edges and fed by pipes 37 connected with suitable mixing and control devices. A lining 38 and an opening restriction plate 39 at each end conserves heat.

Means are further provided for energizing the electrodes of the tubes to bring up the temperature of these parts for outgassing them during exhaust. We accomplish this in our improved apparatus by supplying electrical energy to the tubes on the moving frame through a slidable contact mechanism including brushes, generally indicated by numeral 41 in Figure 3, mounted on the back sides of the carriages and engageable with fixed annular buss bars, generally indicated by numeral 42, disposed centrally of the machine. These buss bars are supported by insulators 43 on a circular subframe 44 rigidly suspended from cross bars 11 on the main frame. Brushes 41 are likewise supported on insulators 46 projecting from the back of the carriages, arranged in horizontal alignment with the buss bars.

In the diagrammatic view of Figure 6 the buss bars are laid out in concentric circles to avoid confusion, it being understood that the bars have equal radii in the actual machine. For further simplicity, connections to only one tube are shown, and the power supplies are indicated diagrammatically. Numerous devices, such as switches, overload cut-outs, and various control means are omitted from the diagram, since these are conventional devices and may be supplied wherever needed or desired as will be readily understood by those skilled in the art. The diagrammatic view will be referred to in greater detail in the following discussion relating to the operation of our apparatus.

Operation

Referring to Figure 1, the station between barriers 47 and 48 is provided for operators who seal off completed tubes from the manifolds and seal on new tubes to be evacuated. With a wheel rotating counterclockwise as viewed in Figure 1, the seal-off operator works adjacent barrier 47 and the seal-on operator works adjacent barrier 48. Based on a four hour cycle (the wheel making one revolution in four hours), the time for a point on the wheel to travel from barrier 47 to barrier 48 is about 36 minutes, which gives ample time for the sealing operations. A suitable switch mounted on carriage 12 enables the operator to stop a pump motor 29 while sealing on new tubes. Otherwise the vacuum pumps operate continuously during the cycle. A single tube will now be followed around the cycle since all tubes proceed in a like manner.

The next period of tube travel, from barrier 48 to barrier 49, takes about 41 minutes, approximately 30 minutes of which the tube is in oven 33. An oven temperature of about 450° C. is preferably maintained. This is sufficient to drive occluded gases out of the glass envelope. Gases bleeding out of the walls into the interior of the tube are of course withdrawn by the pump. After leaving the oven the tube is cooled somewhat by an air blast from blower 51.

The tube then travels between barriers 49 and 52, taking about 15 minutes. An operator working at this station hooks up the various connections with the tube leads. As shown in Figure 4, wire connections having suitable clips are provided at the front of the carriage, including a wire 53 for engaging plate lead 19, a second wire 54 for engaging grid lead 21, and a pair of wires 56 for engaging filament leads 22. These wires form part of circuit connections between the electrodes and the brushes. As seen in Figure 6, filament connections 56 are hooked to the secondary of a transformer 57, the primary of which is connected to brushes 58 and 59. Grid connection 54 terminates at brush 61, and plate connection 53 terminates at brush 62. Another connection 63 is made between the filament circuit and still another brush 64, this connection and brush

being for the purpose of completing the plate and grid circuits so that space current will flow. While the brushes all happen to be shown in contact with buss bars in Figure 6, it is understood that there are times when the brushes are not riding on the bars. In fact, all the circuits are open along the path of tube travel between barriers 47 and 52, by reason of the absence of sections in the buss bars between these points.

After passing barrier 52 from the hook-up station the filament 16 of the tube is energized. In a tube having a 5 volt filament of thoriated tungsten the filament is preferably brought up by applying 3 volts for about ½ minute, then flashed at 8 volts for about 2½ minutes, and then held at about 7 volts for the remaining period of the exhaust procedure. Filament current is supplied from a suitable source 66 of alternating current through buss bars associated with brushes 58 and 59. One of the bars 67 is a continuous ring connected with the source by a feeder 68. The other bar is split into three segments comprising two short segments 69 and 70, and a long tail segment 71. Segments 70 and 71 are supplied with the required potentials from source 66 through feeders 72 and 73, the voltage being dropped between segments 70 and 69 by a resistor 74. Brush 59 thus first engages segment 69, then segment 70, and finally rides along segment 71.

The length of brush ride on segment 71 depends upon the size of the tube and nature of its electrodes, since it is during this period that the plate and grid are outgassed by heating under electron bombardment from the filament. For example, with a tube having a cage-type platinum grid and a cylindrical tantalum plate ¾ inch in diameter and 1 inch long, the total outgassing period is about 138 minutes. This together with the speed of the rotating frame or wheel determines the length of segment 71, as will be readily understood.

After the filament has been flashed the plate 18 is heated to a predetermined temperature for a preliminary outgassing period. In the tantalum plate tube taken for example the plate is gradually heated over a period of about 30 minutes to about 1400° C.; this and other electrode temperatures mentioned herein being "brightness" temperatures as read on an optical pyrometer scale. The heating is accomplished by applying a positive potential to the plate to cause bombardment thereof by electrons evaporated from the filament, the heat being due to the energy given up to the plate when the fast moving electrons are suddenly stopped. Positive potential is supplied from a suitable source 76 of direct current through buss bars associated with brushes 62 and 64. One of the bars 77 is a continuous ring connected with the negative side of the source by a feeder 78. The other bar includes three leading segments 79 connected by feeders 81 with different potential levels at the positive side of the source, the positive potentials applied to the plate increasing at say 10 minute intervals as the brush advances from segment to segment. These potentials are adjusted to elevate the tantalum plate to the temperature above mentioned. In order to prevent excess plate current from flowing due to gas ionization in the tube, suitable resistors 82, such as lamp banks, are interposed in lines 81. After brush 62 leaves the third segment there is an interval when no potential is applied to the plate.

During this interval grid 17 is heated to a predetermined temperature for a preliminary outgassing period. In the platinum grid tube taken for example the grid is heated to about 1300° C. for about 6 minutes. Positive potential is applied to the grid from a suitable source 83 of direct current through buss bar 77 (which is common to both sources) and through another buss bar associated with brush 61. The latter bar includes three short leading segments 84 connected to the positive side of source 83 by lines 86. These lines are all connected together, but the two going to the first two segments include lamp bank resistors 87 for limiting current in event of excessive gas ionization. The positive potential applied to the grid during this preliminary heating period is adjusted to elevate the platinum grid to the temperature above mentioned.

Next, both the plate and grid are heated simultaneously for a prolonged period of about 100 minutes, the plate being maintained at about 1400° C. and the grid at about 1250° C. This is accomplished by long tail segments 88 and 89 of the plate and grid buss bars, these segments being connected to the respective power supplies by lines 91 and 92. The positive potentials applied to the plate and grid are adjusted to maintain the above temperatures, as will be readily understood. Since the initial burst of gas was removed from the electrodes during the preliminary heating periods, there is little danger of excessive gas ionization during the subsequent prolonged heating period, and therefore it is unnecessary to provide current limiting resistors in lines 91 and 92. The simultaneous heating of the electrodes for the time and at the temperatures above specified removes substantially all of the releasable gases from the tantalum plate and platinum grid. It is understood that during all of these outgassing periods the vacuum pump is operating continuously.

After the simultaneous heating period the platinum grid is preferably heated for an additional period of about 2 minutes. This final clean-up of the grid alone is not always necessary, but the step is preferably included to insure removal of residual traces of gas. As shown in Figure 6, the grid buss bar 89 is slightly longer than plate bar 88, to continue application of potential to the grid for the period above stated. The filament buss bar 71 is of course coextensive with grid bar 89.

It is understood that the above pumping schedule is merely given as an example to illustrate the operation of the machine. The pumping schedule may be varied within wide limits, depending upon the type of tube and the size and character of electrodes therein. This will be obvious to those skilled in the art. Thus, it may be desirable to outgas the grid before the plate during the preliminary heating periods, in which case segments 84 of the grid buss bar would be located ahead of plate bar segments 79. The length of the heating period for any given electrode or electrodes may be varied by increasing or decreasing the length of the buss bar segments. In any case the buss bars and associated brushes provide means for automatically timing the electrode heating periods with the progressive movement of the tubes.

Heat treatment of the electrodes ceases as brushes 59 and 61 ride off buss bar segments 71 and 89, all of the circuits to the electrodes being opened by this time. A tube then advances in front of a blower 93 (Figure 1) to cool the

envelope for subsequent handling. Finally the tube passes barrier 47 into the station where an operator removes the tube by sealing off tubulation 14.

From the foregoing it will be seen that our method involves moving the tube along a path, and, while the tube is in motion, exhausting it and simultaneously heating an electrode therein. It will also be seen that the heating of selected electrodes is controlled by timing the periods of electron bombardment with the tube movement, in accordance with a prearranged exhaust schedule. This automatic control eliminates the human equation during the exhaust procedure, whereby a greater degree of uniformity is attained between tubes. Since completed tubes are constantly being removed and replaced by new ones, the exhaust process is a continuous one, well adapted for large scale production. Furthermore the mounting of the vacuum pump for movement with the tube eliminates the need for rotatable joints or the like in the vacuum line, thereby materially improving the degree of high vacuum attainable in the tube. This together with the automatic timing of the exhaust procedure produces superior tubes having uniform characteristics.

We claim:

1. The method of evacuating a tube having an envelope enclosing a cathode and another electrode, which comprises moving the tube along a path, and, while the tube is in motion, exhausting the envelope and bombarding said other electrode with electrons from the cathode, said bombardment being timed with the motion of the tube.

2. The method of evacuating a tube having an envelope enclosing a plurality of electrodes, which comprises moving a tube along a path, heating selected electrodes by electron bombardment during predetermined periods of said movement, and exhausting the envelope during said periods.

3. The method of evacuating a tube having an envelope enclosing a cathode and another electrode, which comprises moving the tube along a path, energizing the cathode during said movement to provide a source of electrons, and applying a positive potential to the other electrode during a predetermined period of said movement and in timed relation with such movement.

4. The method of evacuating a tube having an envelope enclosing a cathode and a pair of other electrodes, which comprises moving the tube along a path, energizing the cathode during said movement to provide a source of electrons, and applying positive potentials to first one and then another electrode of said pair during predetermined periods of said movement.

5. The method of evacuating a tube having an envelope enclosing a cathode and plate and grid, which comprises moving the tube along a path, energizing the cathode during said movement to provide a source of electrons, applying a positive potential to the plate during a period of said movement, and applying a positive potential to the grid during another period of said movement.

6. The method of evacuating a tube having an envelope enclosing a cathode and plate and grid, which comprises moving the tube along a path, energizing the cathode during said movement to provide a source of electrons, applying a positive potential to the plate during a period of said movement, applying a positive potential to the grid during another period of said movement, and then simultaneously applying a positive potential to the plate and grid during a third period of said movement.

WILLIAM W. EITEL.
JACK A. McCULLOUGH.