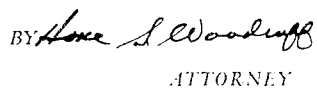


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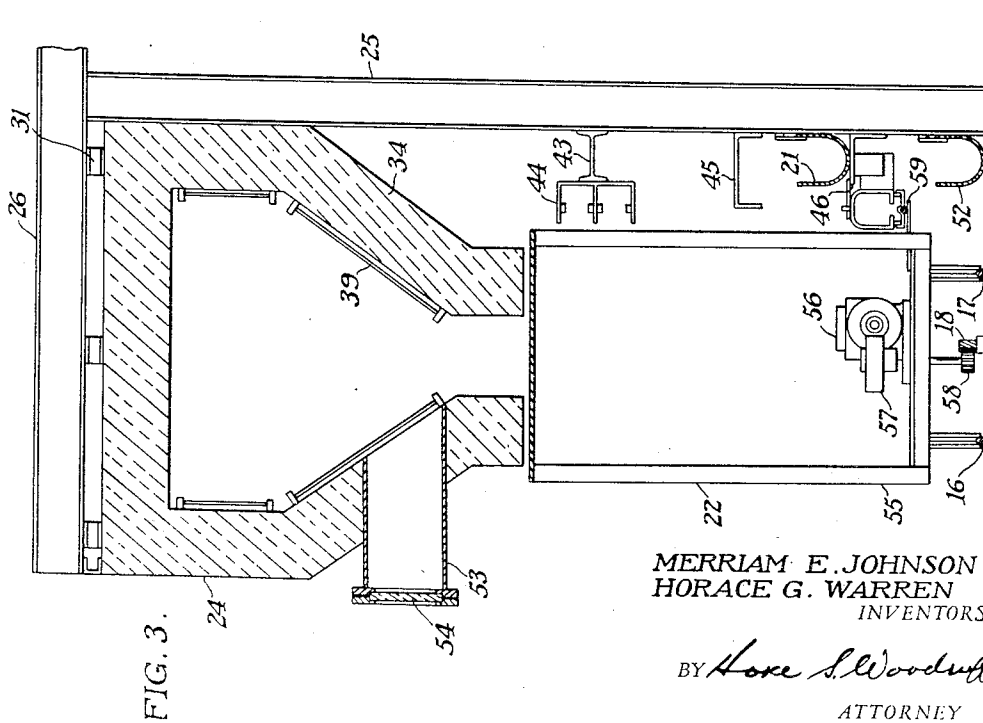
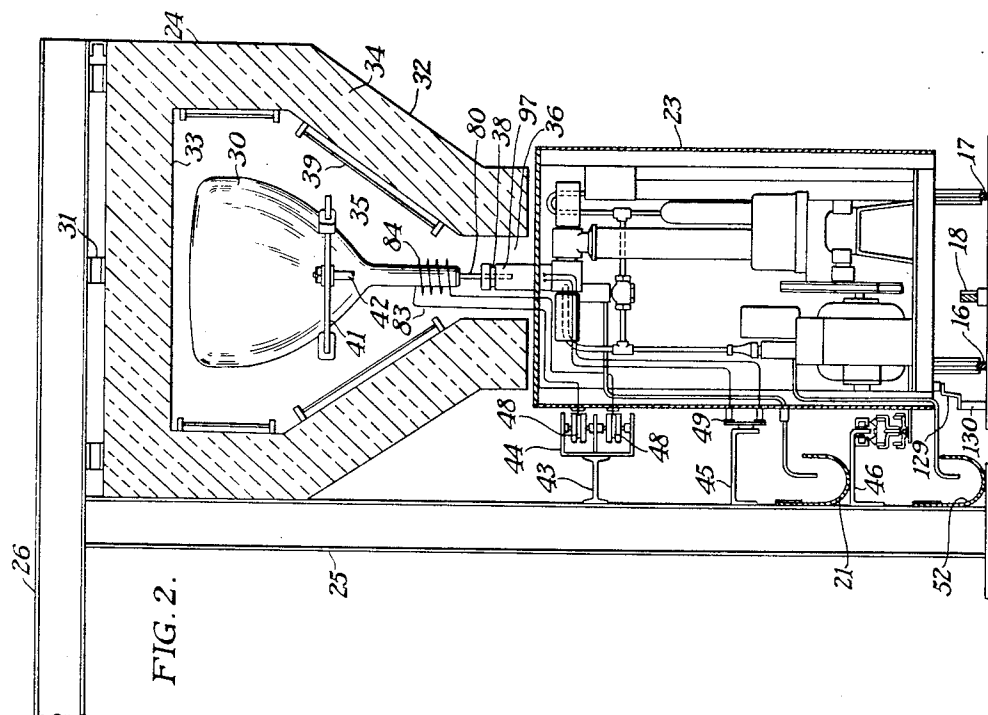
Dec. 5, 1950

M. E. JOHNSON ET AL
APPARATUS AND PROCESS FOR EVACUATING
ELECTRONIC TUBES AND THE LIKE

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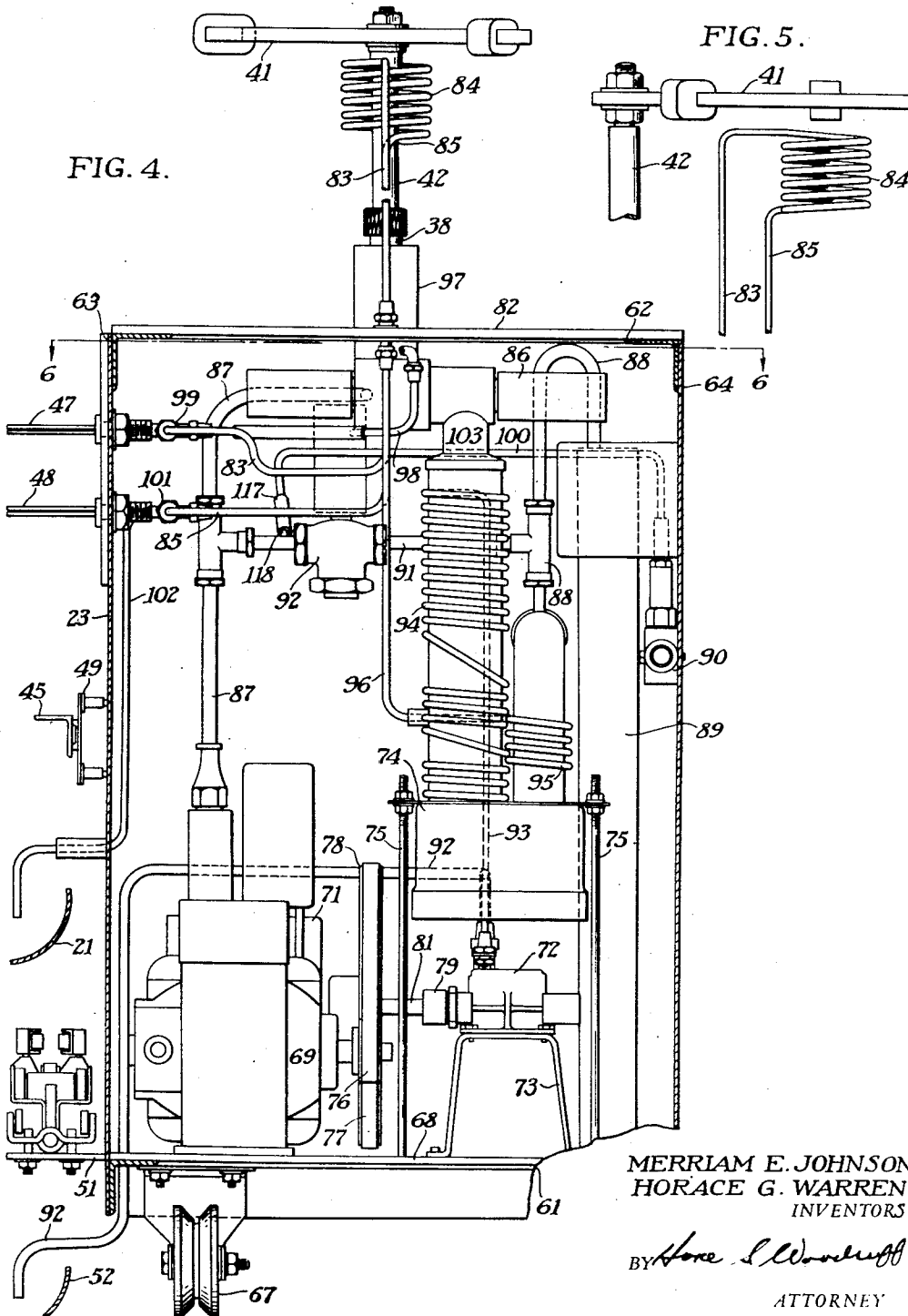
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FIG. 6.

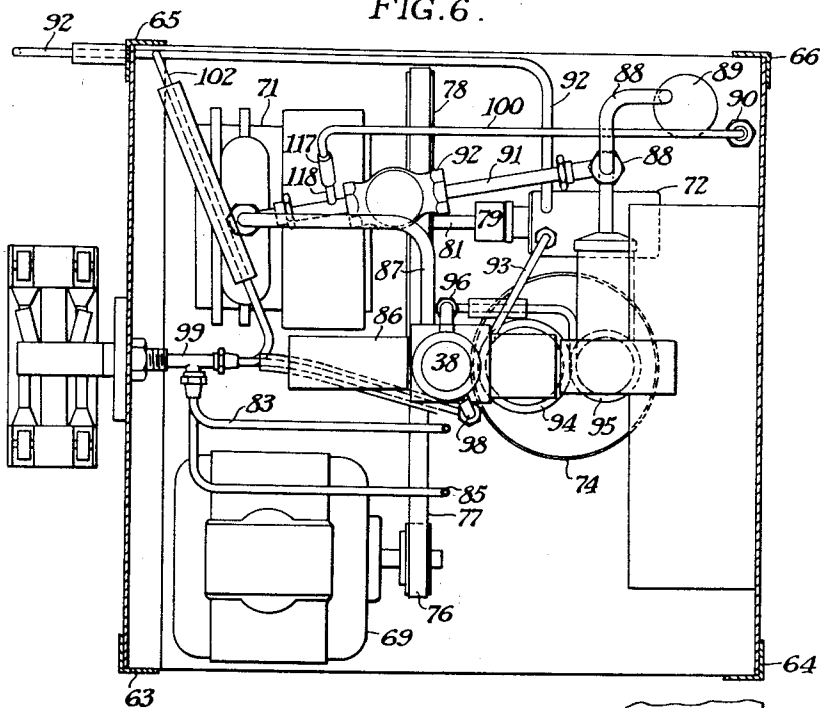


FIG. 7.

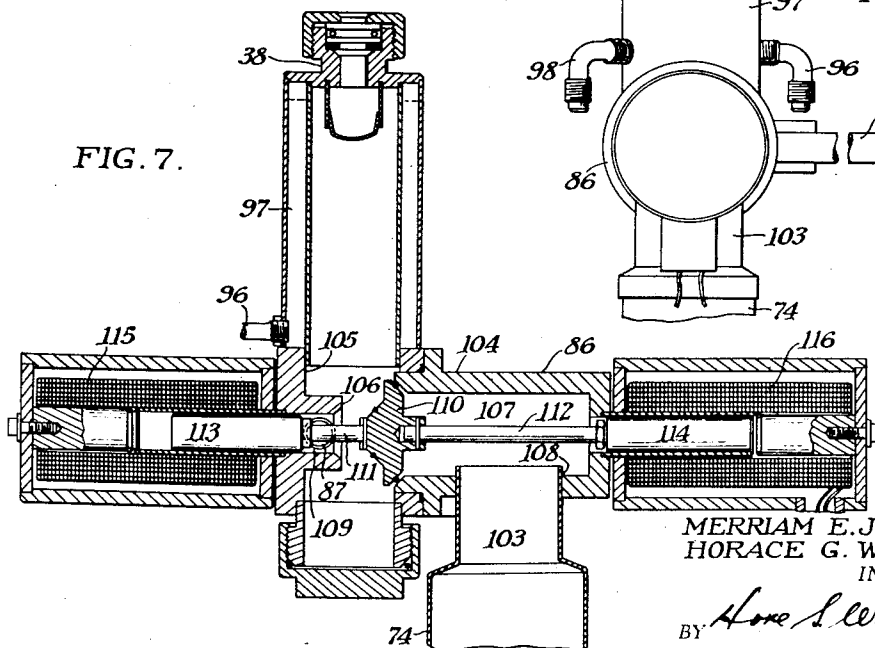
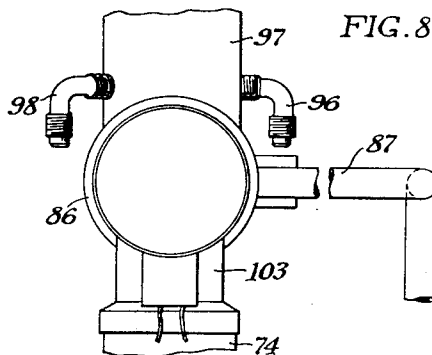


FIG. 8.



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2,532,315

APPARATUS AND PROCESS FOR EVACUATING ELECTRONIC TUBES AND THE LIKE

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Application April 2, 1949, Serial No. 85,204

20 Claims. (Cl. 316—30)

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This invention relates to the manufacture of electronic vacuum tubes such as cathode ray tubes, and more particularly to a novel method and apparatus for evacuating such tubes or other devices which are to be sealed under high vacuum.

Heretofore various methods and apparatus have been devised for the automatic or semi-automatic evacuation of vacuum tubes. Apparatus comprising a turntable which moves the vacuum tubes, while being evacuated, through a heated oven, to a high frequency heating station and to a tube operation station are well known. These have the common disadvantage that in case of a substantial apparatus failure, the apparatus must be stopped for repairs during which production on that apparatus is at a standstill.

An interesting departure from the turntable method is that disclosed in U. S. Patent 2,324,559 of July 29, 1943. As there disclosed a unit vacuum system comprising a motor driven vacuum pump and an electrically heated and water cooled diffusion pump is mounted on a dolly. Vacuum tubes are attached to the system and while being evacuated are moved with the dolly first to an oven, then to a high frequency station and then to a tube operation station. As clearly shown in the patent drawing, the operation at best is only semi-continuous and is not automatic since before being moved to each station, the operator must disconnect the water cooling source for the diffusion pump, move the dolly to the next station and reconnect the water cooling source. Furthermore, while the track aids in the sidewise centering of the dolly at the stations, the lengthwise positioning of the dolly must be accomplished manually by the operator at all three stations and particularly so at the high frequency station where the high frequency coils descend vertically around the tubes. It is also evident that between the oven and the high frequency station the hot tubes are exposed to room temperatures and again is this exposure present between the high frequency station and the enclosed tube operating station. Thus, while this patent discloses to the art one method of removing a unit from the process line without affecting or stopping work on other units, it is accomplished by substituting for the advantages of the automatic operation of the turntable, increased manual operation. This, of course, increases cost of operation and increases the risk of breaking tubes during the operation incident to moving the dolly from one station to the next. The operator is also working on water lines in the vicinity of live electric circuits.

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An object of the present invention, therefore, is improved apparatus and method for evacuating electronic tubes.

Another object of the invention is the provision of apparatus for evacuating vacuum tubes whereby the evacuation, high frequency bombardment of tube elements, tube element operation and water cooling of apparatus may be carried on during the continuous or the intermittent movement of the tube through a baking oven.

Another object of the invention is the provision of apparatus wherein the high frequency bombardment of the tube elements, the tube element operation, and external tube heating may be conducted simultaneously, or in any desired sequence, during progressive movement of the tube from a loading station to a seal-off station and while being continuously evacuated.

Still another object of the invention is the provision of apparatus wherein a plurality of vacuum tubes may simultaneously be individually evacuated by independent vacuum systems and individually subjected to the same or different processing steps, such as high frequency bombardment, tube element operation and external baking while being moved to a seal-off position.

Another object of the invention is the provision of an improved movable car carrying a complete vacuum pumping system including mechanical and diffusion vacuum pumps with the tube to be processed attached thereto.

A further object of the invention is apparatus for controlling temperature surrounding the tube during and between various processing steps.

Another object is to provide continuous water cooling for the diffusion pump and other water-cooled elements mounted on the car during its location in the apparatus.

Still another object is to provide means for automatically moving the car, carrying the tube being evacuated over a track.

Yet another object is improved apparatus and process for the evacuation of cathode ray tubes.

Other objects will appear hereinafter.

These and other objects are attained by novel apparatus which will be described generally at this point. The apparatus comprises an endless double track above which is mounted an oven open at the ends and bottom. This oven is adapted to heat the glass bulbs of the vacuum tubes or other similar enclosures and expel occluded gases from the interior thereof. Sections of the oven are adapted to be differentially heated so that a predetermined temperature gradient can exist in the oven and the outlet sections of the oven may be maintained at lower tempera-

tures to prevent too sudden cooling of the hot vacuum tubes. Four-wheeled cars are provided to traverse the track and each car carries a complete and independent vacuum pumping system including a single water-cooled exhaust socket which extends upwardly from the car into the oven. The vacuum tube to be evacuated is inserted into the socket. Each car carries only one tube and the cars are coupled in a train and follow one another through the processing apparatus. While the exhaust sockets and tubes pass through the oven, the cars and their equipment move along the track beneath the oven and, therefore, the cars are not exposed to the oven temperatures. A water-cooled high frequency inductance coil is also mounted on each car to extend upwardly from the car into the oven and to encircle a portion of the tube, which is supported by the exhaust socket. When a high frequency current is applied to the coil the metal elements of the tube are outgassed by induction heating during movement of the tube through the oven. The exhaust socket also carries terminals of a tube energizing circuit by means of which certain of the tube elements can be energized and heated simultaneously or in desired sequence with the induction heating of the elements during the travel of the cars through the hot oven.

The independent vacuum pumping system carried by each car, also includes in addition to the exhaust socket, a motor driven mechanical type vacuum pump, a water-cooled and electrically heated diffusion pump and a ballast tank in fluid connection with the input side of the mechanical pump and the output side of the diffusion pump. The exhaust socket is adapted to be connected exclusively to either the mechanical pump or to the diffusion pump. There are provided suitable valves and pipe connections between the two vacuum pumps and the ballast tank and the exhaust socket so that on the initial pumping out of the tube, the tube envelope or bulb is connected through the exhaust socket directly and automatically by a solenoid operated valve to the mechanical pump. During this period the connection between the exhaust socket and the diffusion pump is closed by another automatically actuated solenoid operated valve, and the diffusion pump discharges only into the ballast tank. The connection between the ballast tank and the mechanical pump is closed also by another automatically actuated solenoid operated valve. When the pressure in the tube is lowered by the mechanical pump to a desired point, the solenoid operated valves are automatically actuated to close the connection from the tube to the mechanical pump and to open the connection between the tube and the diffusion pump and to open the valve between the ballast tank and the mechanical pump. Thus, at this point of operation the path of the evacuated gas is from the tube and exhaust socket through the diffusion pump, and to the mechanical pump. This operation results in rapidly producing a high vacuum in the tube envelope.

In the event a leak develops in the tube during the evacuation and processing of the tube, the increase in gas pressure in the vacuum system acting on pressure responsive means associated therewith will automatically cause the solenoid valves to be restored to their initial position so that the diffusion pump will be closed off from the defective tube and will discharge only into the ballast tank. The tube will, therefore,

be connected directly to the mechanical vacuum pump. The pressure actuated means, which may be a bellows type switch or a discharge tube, also acts to open the heating circuit for the electrically heated diffusion pump and thus the diffusion pump quickly cools to a lower temperature. While the car carrying the defective tube continues along with other cars through the oven, it will be understood that it has no disadvantageous effect on the tubes being processed on the other cars. This is an important feature of the present invention since it permits continuous production on the lot of tubes irrespective whether one or more is defective.

Also carried by each car is a motor-driven water pump and a motor suitably connected to the water pump and the mechanical vacuum pump for driving them. Mounted adjacent to the endless track is a pair of endless gutters one of which contains a water supply and the other of which serves as a discharge gutter. The cooling system for the diffusion pump, the exhaust socket, and the high frequency coils and high frequency electric terminals is in fluid connection with the water pump which receives the water from the supply gutter through a conduit mounted on the car and immersed in the water during the travel of the car over the track. After passing through the cooling circuit the water is discharged through another pipe extending from the car into the discharge gutter. Each car carries a plurality of electrical contacts which extend therefrom and contact a corresponding number of bus bars positioned adjacent the track which carry suitable electrical currents for operating the electrical devices on the car. The bus bars may be arranged to permit simultaneous or sequential operation of the inductance heating and tube element heating while the cars are moving along the track. The car also carries a trigger switch member which is actuated by trip mechanisms positioned adjacent the track. This switch acts to open and close the circuits associated with the solenoid valves and to operate the valves as described herein. There is also provided means for moving the train of tube-carrying cars along the track. In accordance with one embodiment of the invention, an electric locomotive is provided for hauling the tube-carrying cars over the track. The locomotive motor receives current through a moving contactor extending therefrom and contacting the same bus bar that supplies current to the motor on the tube-carrying car. If desired, the cars may be pushed along the track by a hydraulic piston in which case the locomotive would not be employed.

Assuming that a plurality of cars each loaded with a vacuum tube is being moved along the track as a train and the apparatus is in proper operation, the situation can occur where the tube loading operator is placing a tube in the exhaust socket of the last car of the train of cars and the seal-off operator is preparing to seal off the fully evacuated tube in the first car of the train which is emerging from the exit end of the oven. It will thus be apparent that at the same time in the apparatus there will be tubes passing through the oven which are being only rough pumped, tubes which are under high vacuum, tubes which are being inductively heated, tubes through which a heating current is flowing, and other tubes which are at the required high vacuum and are being cooled gradually in prepara-

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tion for emerging from the oven. From time to time owing to tube or apparatus failure there may be tubes progressing through the apparatus which are defective or at least not being properly processed. However, since each tube is individually processed, these tubes will not affect the processing of any other tubes, and the defective car or tube as the case may be can be removed from the train without substantially interfering with production.

The invention will be further apparent from the following detailed description and drawings in which similar parts bear the same numerals. As shown in the drawings:

Fig. 1 is a schematic plan view of the apparatus for processing electronic vacuum tubes showing a suitably shaped guiding track, the oven positioned thereover, the general location of the high frequency heating zones and the cathode heating zone, a locomotive and movable cars at the loading zone, and other features which will be described hereinafter;

Fig. 2 is a cross-sectional view in elevation of a portion of the apparatus taken on the lines 2—2 of Fig. 1 showing one of the processing cars and its associated mechanisms on the track under the oven; and the vacuum tube mounted thereon passing through the oven;

Fig. 3 is a cross-sectional view in elevation of a portion of the apparatus taken on lines 3—3 of Fig. 1 showing the locomotive on the track passing under the oven;

Fig. 4 is an enlarged end view in elevation of the car shown in Fig. 2 showing further details of the apparatus carried by the car;

Fig. 5 is a side view of the inductance coils shown in Fig. 4.

Fig. 6 is a plan view of the car and its apparatus taken on the line 6—6 of Fig. 4.

Fig. 7 is a cross-sectional view in elevation showing the exhaust socket and the alternate connections through the double solenoid operated valve to the mechanical vacuum pump and to the diffusion vacuum pump;

Fig. 8 is an end view in elevation of Fig. 7, with portions broken away, of the double solenoid operated valve positioned between the exhaust socket and the diffusion pump, and also showing the vacuum connection to the mechanical vacuum pump;

Fig. 9 is a side view of the hydraulic ram device for moving the cars over the track;

Fig. 10 is a circuit diagram showing the electrical circuits for operating the solenoid valves.

Referring to Fig. 1 there is shown an endless track 15 comprising a pair of rails 16 and 17. Between these rails is an endless rack 18 which cooperates with a driven spur gear 58 on locomotive 22, see Fig. 3, to cause the progression of the locomotive along the track. An endless current feed rail is shown at 19 and one of the water gutters is shown at 21. It will be understood that the track, rack, feed rail and gutter are mutually concentric. A locomotive 22 and vacuum tube carrying cars 23 are shown positioned to move along the track in a counterclockwise direction. The vacuum tubes are shown on the cars at 30. It is desirable to operate the process with a sufficient number of cars on the track so that one or more cars are emerging from the oven while one or more cars at the end of the train are ready to enter the oven.

As is apparent from Fig. 1, the U-shaped heating oven 24, for heating the vacuum tubes 30 carried by the cars, is positioned above the track

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on I beams 25 and is further supported by cross beams 26 and 27. The oven 24 extends over one end and two sides of the elliptical track thereby leaving one end of the track exposed and permitting easy access for loading the tube on the car at position 28 and for sealing off tubes at position 29. Any of the tube-carrying cars can be removed from the track, after they leave the oven, and can be rolled away for servicing if the need arises and additional cars can be placed on the track adjacent the loading position.

The operation of the apparatus will be further apparent by reference to Fig. 2. As there shown the oven 24 is directly attached to the vertical beams 25 and to horizontal beams 26 by members 31. The oven 24 comprises an outer wall 32 and inner walls 33 between which is packed suitable insulating material 34. The oven heating space 35 may be of any desirable shape and as shown is of the general contour of the tube 30 being processed. The oven is open at its ends, and at the bottom throughout its length leaving a space 36 through which extends the exhaust socket 38 of the vacuum apparatus carried by car 23. On the inside of the oven are resistance heaters 39 which may be selectively operated for heating the oven and tube passing therethrough. A tube encircling support 41 is shown engaging tube 30 and is mounted on rod 42 which is attached to car 23.

Mounted on a plurality of the support beams 25 is a bus bar 43 with associated contact members 44 for supplying a high frequency current source. Also mounted on support beams 25 is a bus bar 45 for supplying source of current for the cathode heater, and a bus bar 46 is also mounted on beams 25 for supplying current to the motor on the car 23 as well as that of locomotive 22. Contacts 47 and 48 are mounted on car 23 and are adapted to engage contacts 44. Likewise contacts 49 engage bus bar 45 and contact 51 engages bus bar 46. As apparent in Figs. 1 and 2 the bus bars for the high frequency current and for energizing the tube circuit are positioned beneath the oven and extend for less than the total length of the oven. It is evident that these respective bus bars may be made longer or shorter depending on the particular requirements of the tube being processed. Also by insulating the surface of the bus bars or by other suitable means the particular treatment may be carried out intermittently. Gutters 21 and 52 are also mounted on support members 25. The car 23 and its associated vacuum exhaust apparatus will be described in more detail subsequently in connection with Fig. 4. The bus bars are insulated from member 25 and each other.

Referring to Fig. 3 one of the sight tubes 53 is shown extending through the outer wall of the oven and closed by a window 54. This permits a supervising operator to view the tubes during the evacuation and other treatment. More than one such window may be provided as indicated in Fig. 1. The other elements of the oven have been described above. Beneath the oven 24 is a four wheeled locomotive 22 comprising a box-like frame work 55 on which is mounted a motor 56 and gear system 57 which is adapted to rotate spur gear 58 in rack 18. A contact 59 movably engages bus bar 46 to supply current to the motor 56.

In Figs. 4 and 6 the car 23 and its associated apparatus is shown in more detail. It will be apparent that the car comprises a lower rectangular

frame 61 and an upper rectangular frame 62 which are joined at their corners by four angle irons 63, 64, 65, and 66. Grooved wheels 67 support the car 23 on track 15, and are attached to the corners of frame 61. A floor 68 is supported on frame 61. Supported by floor 68 is electric motor 69, mechanical vacuum pump 71, and ballast tank 89. A water pump 72 is supported on brackets 73 attached to the floor. An electrically heated, water-cooled diffusion pump 74 is supported on a pair of rods 75 which in turn are supported by the floor. Extending from the side of the car 23 is a contact 51 which is adapted to contact bus bar 46 and carry a current to electric motor 69. The motor 69 transmits torque to pulley 76 and the mechanical vacuum pump 71 through belt 77 and pulley 78. The water pump 72 is driven through its shaft 79 which engages the shaft 81 of the mechanical pump 71 and the water pump is thus operated whenever the mechanical pump operates. A trigger switch 129 is mounted at the bottom of the car and it is adapted to be tripped by member 130 as the car moves over the track, as described hereinafter.

A platform 82 is supported by upper frame 62 and tube support 41 is attached thereto by a pair of rods, one of which is shown at 42. Extending through platform 82 is exhaust socket 38 into which the tubulation 80 of the tube 30 is inserted, see Figs. 2 and 7. Also extending through the platform 82 are the conduits 83 and 85 of the high frequency coil 84.

Beneath the exhaust socket 38 and in fluid connection therewith is the double solenoid operated valve 86 shown in more detail in Figs. 7 and 8. This valve operates to initially connect the exhaust socket 38 through pipe 87 with the mechanical vacuum pump 71 and at the same time closes the path in the valve between the exhaust socket and the throat 103 of diffusion pump 74. The circuit including the trigger operated switch 129 for operating this valve is shown in Fig. 10.

Assuming that the diffusion pump 74 is operating continuously it will now discharge through pipe 88 into ballast tank 89, the by-pass pipe 91 between pipes 88 and 87 being closed by another solenoid valve 92. The circuit for operating this valve 92 is also shown in Fig. 10.

When the pressure in the tube being evacuated reaches a predetermined value, solenoid valve 86 is actuated by switch 129 which is tripped by member 130 to close the path through the valve to pipe 87 and to open the path through the valve to the diffusion pump 74. At the same time solenoid valve 92 will open pipe 91 so that the gas being evacuated will flow from the exhaust socket through the diffusion pump and by pipes 88, 91 and 87 to the mechanical vacuum pump. The mechanical pump thus operates as a backing pump for the diffusion pump and a high vacuum will be produced in the tube.

If at this time while both the diffusion pump 74 and the mechanical pump 71 are working in series to maintain a high vacuum in the tube 30, a leak occurs in the tube, or elsewhere in the vacuum system, the gas pressure immediately increases considerably in the vacuum system. To prevent such gas pressure from damaging the diffusion pump, a pressure actuated bellows switch 90 is provided which, on a predetermined pressure gain in the vacuum system, will restore the valves to their original positions so that the tube will again be connected directly to the mechanical pump 71, and the diffusion pump 74 will

be closed off from the leaky tube 30 in the manner heretofore described. The pressure actuated switch 90 also acts to open the heater circuit for the diffusion pump thereby causing it to stop functioning. The pressure actuated switch 90 is shown both in Figs. 4 and 6 and is in fluid connection with the vacuum system pipe 91 through pipe 100, insulating conduit 117 and pipe 118. The circuit diagram for this operation is shown in Fig. 10.

The water cooling circuit will now be described. Water from any suitable source is maintained in gutter 52. Pipe 92 extends from the side of the car 23 and is adapted to travel with the car and be immersed in the water. This pipe is attached to the inlet side of water pump 72 and when the pump operates it pumps water through pipe 92 to pipe 93 and respectively to cooling coils 94 and 95. The water then flows through pipe 96 to the water jacket 97 of exhaust socket 38. The cooling water leaves the water jacket 97 through pipe 98 and at pipe junction 99 enters the inlet pipe 83 of the high frequency coils 84 and leaves through pipe 85 and at pipe junction 101 enters discharge pipe 102 and continuously discharges into gutter 21.

The operation of the double solenoid operated valve 86 will be more clearly understood by reference to Fig. 7. As shown, the valve comprises an air tight casing 104 having an aperture 105 therein adapted to receive the exhaust socket 38 in fluid communication with the valve chamber 106. A second chamber 107 is in fluid communication with chamber 106 and has an aperture 108 therein so that the throat 103 of the diffusion pump 74 can be attached in fluid communication therewith. A third chamber 109 is also in fluid communication with chamber 106 and pipe 87 is connected thereto. A valve closing member 110 is positioned to move horizontally in chamber 106 and to close alternately the respective opening into chamber 107 or 109. As clear in the drawing, member 110 is supported by rods 111 and 112 which respectively engage the armatures 113 and 114 of solenoids 115 and 116, which are mounted in suitable casings. Thus as previously described the exhaust from the tube being pumped can be directed exclusively to the mechanical pump through pipe 87 and then exclusively to diffusion pump 74, depending on the actuation of the respective solenoids. Fig. 8 is an end view of the solenoid valve particularly showing pipe 87 and the water cooling circuit for the exhaust socket.

Referring to Fig. 9, the hydraulic ram type of indexing and forward movement mechanism for moving the cars 23 along the track is shown. This mechanism may be employed instead of the locomotive 22, but it is possible to coordinate the action of both devices so that the locomotive will continuously move the cars during ordinary operation and the hydraulic ram can be employed to index the cars if need arises at the seal-off or loading positions when the locomotive might be temporarily stopped. This mechanism, as shown in Fig. 9, comprises a double acting hydraulic cylinder 170 having a piston rod 171 extending from one end and a piston rod 172 extending from the other end. These pistons move to and fro as fluid is forced alternately into the cylinder through parts 173 and 174. A side arm 175 is attached to the pistons at 177 and 178 and and parallels the movement of the pistons. Spring loaded dogs 179 are spaced along the side arm 175 at approximately the distance between

car lengths. The front side 181 of the dogs is straight, but the rear side has a beveled face 182. This ram is mounted on member 180 and at one side of the track as shown in Fig. 1, and the dogs 179 extend downwardly toward one edge of the cars 23 when the cars are positioned on the track. The cars to be moved by this ram mechanism each have a projection 183 extending upwardly from the front corner of the car and these projections are positioned to engage the spring loaded dogs 179. The front face 184 of the projections 183 is beveled, and the rear face 185 is straight. Thus, on the forward movement of the piston, the dogs 179 will engage the projections 183 of the cars and move the cars over the track corresponding to the distance the pistons are moved. The pistons are then retracted to the position shown by the dotted lines, and the dogs 179 slide backwardly over the projections 183 without moving the cars. The hydraulic cylinder is supplied with fluid under pressure by any conventional pump mechanism, as will be understood. Motors of the pumps may be controlled by a timing mechanism, although the cylinder can be operated manually.

Referring to Fig. 10, there is shown a circuit diagram for the operation of certain of the electrical devices carried by each car, which receive actuating current through movable contact members 51. The operating current for motor 69 is carried from contact 51 through wire 120 to motor 69 and thence by wire 121 to ground. The motor thus runs continuously when a car 23 is placed on the track. The current for heating the diffusion vacuum pump flows through contact 51, wires 120 and 122, normally closed relay contacts 123, wire 124, resistance heaters 125, and by wire 126 to ground. The current for operating the solenoid operated valves is conducted from contact 51 through wire 127 to trigger switch 129. This switch has a pair of contacts 131 and 138 adapted to be selectively connected to the current source by switch arm 128. As shown in the drawing, switch arm 128 is in contact with contact 131; and the current, therefore, flows through wire 132, rectifier 133, wire 134 to the solenoid of solenoid operated valve 92, through wire 135 to ground. This closes valve 92 and the connection between the two pumps, as previously mentioned (see Fig. 4). The current for the operation of one of the solenoids 116 of double solenoid valve 86 flows from rectifier 133 through wire 136 to solenoid 116 and thence by wire 137 to ground. This closes the valve in the connection between the exhaust socket 38 and the diffusion pump 74 and opens the valve in the direct connection between the exhaust socket 38 and the mechanical pump 71. It will be seen that at this point the circuit about to be described through the solenoid 115 of double solenoid valve 86 is open because trigger switch arm 128 does not contact the switch contact 138.

When, as previously described, the trigger switch 129 is again actuated, switch arm 128 will disconnect the current supply wire 127 from switch contact 131 and thus open the circuit through the solenoid of valve 92 and the circuit through solenoid 116 of valve 86. The valve closing member 110 of the double solenoid valve 86 is now free to move. Valve 92 is therefore opened by retraction of its spring, and consequently the connection between the vacuum pumps is opened. The switch arm 128 will, however, close a circuit through switch contact 138, and the current will flow through wire 139 through switch arm 141 of

pressure responsive switch 90, contact 142, wire 143, rectifier 144, wire 145, to solenoid 115 of solenoid valve 86, and by wire 146 to ground. The energizing of solenoid 115 moves the valve closing member 110 to the left and opens the connection between exhaust socket 38 and the diffusion pump 74 and closes the connection between the exhaust socket and the mechanical vacuum pump (see Fig. 7). Of course, this takes place simultaneously with the opening of valve 92, and at this time the gas being evacuated through the exhaust socket 38 flows first through the diffusion pump and thence to the mechanical vacuum pump. If, during this setting of the trigger switch and of the valves, a leak occurs in the system, pressure-responsive switch 90 is operated to disconnect its switch arm 141 from contact 142. This opens the circuit through solenoid 115, and valve-closing member 110 is free to move. Switch arm 141 now engages contact 147, and current flows through relay 151 from wire 127 through switch 128, switch 90, wire 149, relay 151, wire 152 to ground. When relay 151 is thus energized, it simultaneously opens relay contact 123, which shuts off heating current through diffusion pump heater 125, and closes relay contact 159 which closes a circuit to energize the solenoid of valve 92 and the solenoid 116 of valve 86. Current flows from wire 127, wire 161, relay contact 159, wire 162 to wire 133 and from thence through the solenoids 92 and 116 as previously described. The exhaust socket is thus again connected directly to the mechanical pump to the exclusion of the diffusion pump which discharges only into the ballast tank. A transformer 155 is placed in parallel with the relay 151, and current is conducted through wire 153, the primary winding 154, and to ground by wire 158 whenever current flows through the relay. An electric bell 157 is connected to the secondary winding of the transformer and therefore sounds when a leak develops in the vacuum system.

A typical operation of the apparatus for processing a plurality of cathode ray tubes is as follows: The oven would be heated by its resistance heaters to the desired temperature gradient, the maximum temperature being about 500° C. A plurality of cars would be placed on the track adjacent the loading position and coupled to the locomotive. A cathode ray tube would be placed in the exhaust socket of each car. When placed on the track, the electrical contacts on the cars contact the power feed rail which will supply current for operating the motor which drives the vacuum pump and the water pump and also supplies heating current to the diffusion pump. When the tubes are all positioned on the car current is supplied to the feed rail and the locomotive moves toward the oven. As the trigger switch on each car is tripped by the first trip member, the double solenoid valve of each independent vacuum system is automatically actuated to connect the tube envelope directly to the mechanical vacuum pump so that it is initially employed as a roughing pump. This greatly reduces the overall pumping time. At the same time, this mechanism closes the connection between the exhaust socket and the diffusion pump so that it discharges into the ballast tank. Simultaneously the single solenoid operated valve between the diffusion pump and the mechanical pump is closed. When the rough pumping of the tubes has been completed, the double solenoid valve and the single solenoid valve are auto-

matically reversed by the trigger switch which is actuated by the second trip member to close the direct connection to the mechanical vacuum pump and cause the gas being exhausted from the tube to flow directly to the diffusion pump and thence to the mechanical pump. During this time all the cars have been progressing along the track and consequently most all of the tubes are progressing through the hot oven, and the oven heat aids in expelling gas from the glass bulb and tube elements. When the pressure in the tube has reached a predetermined low point, the cathode ray tubes are ready for the formation of a cathode emitter surface. The cathode in each of the cathode ray tubes consists of a tungsten cup indirectly heated by a tungsten filament. The surface of this cup is covered with a preparation of barium and strontium carbonate. Upon application of electric current through the tube operating circuit to the heater and in the rarefied atmosphere of the high vacuum, this carbonate gives up its gases and is converted into the barium and strontium oxides. The resulting gases are, of course, removed from the tube by the pumping system. The barium and strontium oxides which remain on the cathode are the primary source of electrons which cause a television picture to appear on the face of the bulb when it is employed in television equipment.

The outgassing of the other metal elements of the cathode ray tube which are positioned mainly in the neck of the tube is accomplished by the water-cooled induction coil which is in position around the neck of the cathode ray tube. This coil is connected to the terminals located on the carrier which engage the water-cooled bus bar which is connected to the high-frequency generator. This high-frequency bombarding is automatic in operation and is caused by the car turning on a switch after it is in contact with the bus bar, proceeding a desired distance, and shutting off the switch before it leaves the bus bar. This type of mechanism is to prevent arcing of the high-frequency current which has been generated. The formation of the cathode emitter and the outgassing of the other elements may occur in any sequence. The expelled gas is withdrawn through the vacuum system. The tubes continue through the oven and are cooled somewhat by passing through the lower temperature oven sections adjacent the oven outlet.

When the cars emerge from the oven, the pressure in each tube should be sufficiently low to permit sealing off of the tubes which may be done in the usual manner, after which a getter in the tubes may be flashed and the tube removed from the socket and taken to the basing operation.

We claim:

1. In apparatus for evacuating in continuous fashion vacuum tubes having metallic elements therein, guiding means, vacuum tube heating means positioned adjacent said guiding means, a plurality of movable members adapted to move along the guiding means, means for moving the movable members, each movable member carrying apparatus comprising an independent vacuum pumping system adapted to evacuate a vacuum tube attached thereto during travel of the movable member, means for supporting the vacuum tube being evacuated in heating relation with the tube-heating means during travel of the movable member, individual means mounted on each movable member for inductively heating

the metallic elements of the vacuum tube during travel of said movable member along said guiding means, means carried by each movable member for supplying an energizing current for the tube elements, and means positioned adjacent the guiding means and in the region of said tube heating means for selectively and sequentially operating the tube energizing and inductive heating means during travel of the moving member and while the tube is in heating relation with the heating means.

2. In apparatus for evacuating in continuous fashion vacuum tubes having metallic elements therein, guiding means, vacuum tube heating means positioned adjacent said guiding means, a plurality of movable members adapted to move along the guiding means and to support a tube to be evacuated in heating relation with said heating means during at least a portion of the movement of said movable member, means for moving the movable members, each movable member carrying apparatus comprising an independent vacuum pumping system adapted to evacuate a vacuum tube attached thereto during travel of the movable member and being operable throughout travel of the movable member, said pumping system including a roughing vacuum pump, a diffusion pump, and an exhaust socket which is adapted to support the vacuum tube being evacuated adjacent the tube heating means during travel of the movable member, means for operating said pumps, valve means for initially connecting the exhaust socket exclusively to the roughing pump, valve means for subsequently connecting the exhaust socket exclusively to the diffusion pump, and means then operable to connect the diffusion pump to the roughing pump, individual means mounted on each movable member for inductively heating the metallic elements of the vacuum tube, means carried by each movable member for supplying an energizing current to the tube elements, and means positioned adjacent the guiding means and in the region of said tube heating means for selectively and sequentially operating the energizing and inductive heating means during travel of the movable members and while the tube is in heating relation with the heating means.

3. In apparatus for evacuating in continuous fashion vacuum tubes having metallic elements therein, guiding means, vacuum tube heating means positioned adjacent said guiding means, a plurality of movable members adapted to move along the guiding means, means for moving the movable members, each movable member carrying apparatus comprising an independent vacuum pumping system adapted to evacuate a vacuum tube attached thereto during travel of the movable member, said pumping system including a mechanically operated roughing vacuum pump, an electrically heated and water-cooled diffusion vacuum pump, a water-cooled exhaust socket which is adapted to support the vacuum tube being evacuated adjacent to and in heating relation with the tube-heating means during travel of the movable member, means for driving said mechanical pump, means for supplying heating current to the diffusion pump, a water-cooled high frequency coil mounted on each movable member for inductively heating the metallic elements of the vacuum tube, means for water-cooling said water-cooled members during travel of said movable members, means carried by each movable member for supplying a high frequency current to said coils, means including the exhaust socket for supply-

ing an energizing current to the tube elements, means including valve means for initially connecting the exhaust socket exclusively to the roughing pump, means including valve means for subsequently connecting the exhaust socket exclusively to the diffusion pump, means including valve means then operable to connect the diffusion pump to the roughing pump, and pressure-responsive means operable on an increase of gas pressure in the vacuum pumping system to reconnect the exhaust socket to the roughing pump, and to disconnect the diffusion pump from the exhaust socket and roughing pump and means positioned adjacent the guiding means and in the region of said tube heating means for selectively and sequentially operating the energizing and inductive heating means during travel of the movable members.

4. In apparatus for evacuating in continuous fashion vacuum tubes having metallic elements therein, guiding means, vacuum tube heating means positioned adjacent said guiding means along a substantial portion of said guiding means, a plurality of movable members adapted to move along the guiding means, means for moving the movable members, each movable member carrying apparatus comprising an independent vacuum pumping system adapted to evacuate a vacuum tube attached thereto during travel of the movable member, said pumping system including a mechanically operated roughing vacuum pump, an electrically heated and water-cooled diffusion vacuum pump, a water-cooled exhaust socket which is adapted to support the vacuum tube being evacuated adjacent to and in heating relation with the tube-heating means during travel of the movable member, means for driving said mechanical pump, means for supplying heating current to the diffusion pump, a water-cooled high frequency coil mounted on each movable member for inductively heating the metallic elements of the vacuum tube, means for water-cooling said water-cooled members, means carried by each movable member for supplying a high frequency current to said coils, means including the exhaust socket for supplying an energizing current to the tube elements during travel of said movable members, means for initially connecting the exhaust socket exclusively to the roughing pump, means for subsequently connecting the exhaust socket exclusively to the diffusion pump, means then operable to connect the diffusion pump to the roughing pump, pressure-responsive means operable on an increase of gas pressure in the vacuum pumping system to reconnect the exhaust socket to the roughing pump, to disconnect the diffusion pump from the exhaust socket and roughing pump, and to shut off the heating current to the diffusion pump, and means positioned adjacent the guiding means and said tube heating means for selectively operating the energizing and inductive heating means during travel of the movable members.

5. In apparatus for evacuating in continuous fashion vacuum tubes, a track, an oven positioned above the track and extending along a substantial portion of the track, a plurality of resistance heaters in said oven adapted to heat the oven, a source of high frequency current adjacent the track, a tube operating current supply adjacent the track, a current supply for operating a motor and for heating a diffusion pump, a water supply and water discharge system adjacent the track, a plurality of cars adapted to move along the track beneath and out of contact with the oven,

each of said cars being adapted to support a tube to be evacuated and to bring said tube into heating relation with said oven during movement along said track, a locomotive for moving the cars along the track, each car carrying apparatus comprising an independent vacuum pumping system including a motor-driven mechanical vacuum pump, an electrically heated and water-cooled diffusion pump, a ballast tank, a water-cooled exhaust socket extending upwardly from the car and adapted to support a vacuum tube within the oven in fluid connection with the vacuum system, a water-cooled high frequency coil mounted on the car and positioned above and concentric with the exhaust socket and adapted to heat inductively a portion of a vacuum tube when the tube is supported by the exhaust socket, a connection between the exhaust socket and the diffusion pump, a direct connection between the pumps, a connection between the exhaust socket and the mechanical pump, a solenoid-operated valve in each of said connections adapted to close the connections when the solenoids of the valves are energized and to open the connections when said solenoids are de-energized, a first circuit including the solenoid of the valve in the connection between the exhaust socket and the diffusion pump and the solenoid of the valve in the connection between the pumps, a second circuit including the solenoid of the valve in the connection between the exhaust socket and the mechanical pump, a trigger switch in said circuits adapted to be first actuated to close the first circuit and open the second circuit and thus effect the closing of the connection between the exhaust socket and the diffusion pump and the connection between the diffusion pump and the mechanical pump and also to effect the opening of the connection between the exhaust socket and the mechanical pump, the switch adapted to be secondly actuated to open the first circuit and close the second circuit and thus effect the opening of the connection between the exhaust socket and the diffusion pump and the connection between the two pumps and to close the connection between the exhaust socket and the mechanical vacuum pump, a pressure-responsive switch in said second circuit and fluidly connected to the vacuum system, adapted on a predetermined increase in gas pressure in the vacuum system to open the second circuit and thus open the connection between the exhaust socket and the mechanical pump, the pressure-responsive switch simultaneously operating to close the first circuit and thereby close the connection between the exhaust socket and the diffusion pump and the connection between the pumps, a motor for driving the mechanical vacuum pump, a water pump driven by said motor, a water conduit system including the water pump for circulating water from the water supply through said water-cooled members and to the discharge system during travel of the car along the track, a pair of contacts electrically connected to the high frequency coils for movably contacting the high frequency current source, another pair of contacts electrically connected to the tube elements for movably contacting the operating current supply, a contact electrically connected to the motor and pump heater for movably contacting said source, the high frequency current supply and the tube operating current supply being arranged to supply current in a predetermined sequence to the cars during the evacuation of the tubes carried

thereon and their progression through the heating oven.

6. A process for manufacturing vacuum tubes having a cathode therein comprising continuously moving a tube over a path, evacuating the tube during the travel over the entire path, inductively heating the tube during movement over a portion of said path, heating the cathode of the tube during movement over another portion of said path, and simultaneously heating the tubes externally during travel over a large portion of said path, including the inductive heating and cathode heating portions.

7. A process for manufacturing vacuum tubes having a cathode therein comprising continuously and successively moving a plurality of the tubes over a path, evacuating the tubes during the travel over the entire path, inductively heating the tubes during movement over a portion of said path, heating the cathodes of the tubes during movement over another portion of said path, and simultaneously heating the tubes externally during travel over a major portion of said path, including the inductive heating and cathode heating portions.

8. A method for manufacturing vacuum tubes having a cathode therein comprising continuously and simultaneously moving a plurality of the tubes in succession over a path, continuously evacuating the tubes during the travel over the entire path, inductively heating the tubes during movement over a portion of said path, heating the cathode of the tubes during movement over another portion of said path, and heating the tubes externally during travel over a portion of said path substantially in excess of the combined extent of said inductive heating and cathode heating portions and including the inductive heating and cathode heating portions, the number of tubes traveling over the path being sufficient so that certain of the tubes are being inductively heated while the cathodes of other tubes are being heated and other tubes are being only externally heated.

9. A process for manufacturing vacuum tubes having a cathode and other metal elements therein comprising continuously and simultaneously moving a plurality of tubes in single file over a path, independently evacuating each individual tube during the travel over the entire path, independently heating each tube by inductive heat during movement over a portion of said path, independently heating the cathode of each of the tubes during movement over another portion of said path, heating the tubes externally during travel over a large portion of said path, including and substantially greater than the inductance heating and cathode heating portions, a plurality of said tubes being heated externally simultaneously the number of tubes traveling over the path being sufficient so that certain of the tubes are being inductively heated while the cathodes of other tubes are being heated, other tubes are being only externally heated, and other tubes are under sufficiently high vacuum to be sealed.

10. A process for manufacturing vacuum tubes having a cathode and other metal elements therein, comprising continuously and simultaneously moving a plurality of tubes in single file over a path, independently evacuating each individual tube during the travel over the entire path, independently heating each tube by inductive heat during movement over a portion of said path, heating the cathode of the tubes during move-

ment over another portion of said path, heating the tubes externally during travel over a portion of said path having an extent substantially in excess of the combined extent of the inductance heating and cathode heating portions and including the inductance heating and cathode heating portions, sealing off completely evacuated tubes, removing the sealed tubes from the process, and then replacing said tubes with tubes to be processed as described.

11. A process for manufacturing vacuum tubes having a cathode and other metal elements therein, comprising simultaneously moving a plurality of tubes in single file along an endless path, independently evacuating each individual tube during the travel over the path from a loading position to and including a seal-off position, independently heating each tube by inductive heat during movement over a portion of said path, heating the cathode of the tubes during movement over another portion of said path, heating the tubes externally during travel over a portion of said path substantially in excess of the combined extent of the inductance heating and cathode heating portions and including the inductance heating and cathode heating portions, cooling the tubes during travel over a portion of said path subsequent to said portion wherein said tubes are heated externally, sealing off completely evacuated tubes at the seal-off position, removing the sealed tubes from the process, and then replacing said tubes at the loading position with tubes to be processed as described.

12. An apparatus for evacuating vacuum tubes having metallic elements therein, said apparatus comprising guiding means, vacuum tube heating means positioned adjacent said guiding means, a plurality of movable members adapted to move along the guiding means, means for moving the movable members, each movable member carrying apparatus comprising an independent vacuum pumping system adapted to evacuate the vacuum tube attached thereto during travel of the movable member, said pumping system including a mechanically operated roughing vacuum pump, an electrically heated and fluid cooled diffusion vacuum pump, a fluid cooled exhaust socket which is adapted to support the vacuum tube being evacuated and to move said tube through the tube heating means during travel of the movable member, means for driving said mechanical pump, means for supplying heating current to the diffusion pump, a fluid-cooled high-frequency coil mounted on each movable member for inductively heating the metallic elements of the vacuum tube, means for cooling said fluid cooled members, means carried by each movable member for supplying a high frequency current to said coil, means including the exhaust socket for supplying an energizing current to the tube elements, means for initially connecting the exhaust socket exclusively to the roughing pump, means for subsequently connecting the exhaust socket exclusively to the diffusion pump, and pressure-responsive means operable on an increase of gas pressure in the vacuum pump system to reconnect the exhaust socket to the roughing pump and to disconnect the diffusion pump from the socket and roughing pump, and means positioned adjacent the guiding means for selectively operating the energizing and inductive heating means during travel of the movable members.

13. Automatically operating apparatus for evacuating vacuum tubes which contain metallic

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elements, said apparatus comprising in combination a track of substantial length, a plurality of cars adapted to move over the extent of said track in succession, means for moving said cars simultaneously, each said car being adapted to carry a single tube to be evacuated, each said car carrying a complete vacuum pumping system comprising a mechanical vacuum pump, a diffusion vacuum pump, an exhaust socket adapted to receive and hold a tube to be evacuated, conduit means connecting said exhaust socket with said pumps, valve means in said conduit means adapted to isolate said diffusion pump from said pumping system during a portion of the movement of said cars along said track and to connect said diffusion pump in operating relation with said pumping system during the remaining movement of said cars along said track, means for actuating said pumps throughout movement of said cars along said track, individual inductance heating means on each said car adapted to inductively heat a tube being evacuated, means associated with a localized zone of said track for energizing said inductance heating means during a portion of the path of travel of said cars along said track, energizing means on each said car adapted to be connected to the metallic elements of the tube carried by said car, means associated with a second localized zone of said track for furnishing electrical current to said energizing means during another portion of the path of travel of said cars along said track, and tube heating means positioned adjacent said track and being adapted to heat said tubes being evacuated during travel of said cars along said track, said tube heating means extending along said track a distance substantially less than the extent of said track but substantially greater than the combined extent of said localized zone in which said inductance heating means is energized and said second localized zone in which current is furnished to said energizing means and including both said localized zones.

14. Automatically operating apparatus for evacuating vacuum tubes containing metallic elements therein, said apparatus comprising in combination guiding means, a plurality of movable members adapted to travel in succession over the extent of said guiding means, means for moving said movable members along said guiding means simultaneously, each said movable member carrying a complete vacuum pumping system including an exhaust socket adapted to receive and support a tube to be evacuated and vacuum pumping means connected with said exhaust socket for evacuating said tube, means for actuating said pumping means throughout the movement of said movable members over said guiding means, individual inductance heating means on each said movable member for inductively heating said tube carried by said movable member, tube energizing means on each said movable member adapted to be connected to the metallic elements of said tube, means in a localized zone adjacent said guiding means adapted to energize each said inductance heating means during travel of the movable member carrying said inductance heating means through said localized zone, means in a second localized zone adjacent said guiding means adapted to furnish electrical current to each said tube energizing means during travel of the movable member carrying said tube energizing means through said second localized zone, and oven means for externally heating said tubes during travel of said movable members along

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said guiding means, said oven means extending adjacent said guiding means a distance substantially less than the extent of said guiding means but including and being substantially longer than the combined extent of both said localized zones.

15. Automatically operating apparatus for evacuating tubes containing metallic elements, said apparatus comprising in combination guiding means defining an endless path of travel for tubes to be evacuated, carrying means for simultaneously and successively moving a plurality of tubes along said path of travel, evacuating means for continuously evacuating said tubes and being operable throughout said path of travel, individual inductance heating means associated with said carrying means for inductively heating each of said tubes in succession during movement of said tubes along said path, individual tube energizing means associated with said carrying means for energizing the metallic elements of each of said tubes in succession during movement of said tubes along said path, means in a localized zone adjacent said guiding means for energizing each said inductance heating means during passage of said inductance heating means through said localized zone, means in a second localized zone adjacent said guiding means for supplying current to each said tube energizing means during passage of said tube energizing means through said second localized zone, and oven means adapted to externally heat said tubes during travel of said tubes along said path, said oven means having an extent substantially less than the extent of said guiding means but substantially greater than the combined extent of said localized zone and said second localized zone and including the extent of said localized zone and said second localized zone.

16. Apparatus for evacuating tubes containing metallic elements, said apparatus comprising guided carrying means constructed and arranged for moving a plurality of tubes simultaneously and in succession over a predetermined path, a plurality of vacuum pumping means on said carrying means and being constructed and arranged for continuously and individually evacuating each of said tubes throughout the extent of said path, a plurality of inductance heating means on said carrying means and being constructed and arranged for individually heating each of said tubes and being operable only in a localized zone along said path, a plurality of tube energizing means carried by said carrying means and being constructed and arranged for individually energizing the metallic elements of each of said tubes and being operable only in a second localized zone along said path, and oven means constructed and arranged for externally heating said tubes during movement of said tubes along a portion of said path substantially less than the extent of said path but including the extent of said localized zone and said second localized zone and substantially greater than the combined extent of both said localized zones.

17. In apparatus for evacuating cathode-type tubes and including means for moving a plurality of tubes simultaneously and in succession over a guided path, means for heating the tubes externally during travel along said path, means for inductively heating the tubes in succession, means for cathodically heating the tubes while said tubes are being heated externally, an individual vacuum pumping system for each said tube, said system comprising an exhaust socket adapted to engage a tube to be evacuated, a

mechanical vacuum pump, a diffusion vacuum pump, a ballast tank communicating with the high pressure outlet of said diffusion pump, conduit means connecting said exhaust socket with the low pressure inlet of said diffusion pump, secondary conduit means connecting said ballast tank with said mechanical vacuum pump, by-pass conduit means connecting said exhaust socket directly with said mechanical vacuum pump, valve means in said conduit means and secondary conduit means, and valve means in said by-pass conduit means, said system being arranged whereby said diffusion pump and ballast tank can be isolated from said system during initial evacuation of the tube being evacuated and included in the system during subsequent evacuation without interrupting the evacuation process.

18. An individual tube evacuating system adapted for use on evacuating apparatus employing a plurality of movable members, each constructed and arranged to support a single tube, said evacuating system comprising an exhaust socket adapted to engage the mouth of a tube to be evacuated in vacuum-tight relation, a mechanical vacuum pump adapted to be used as a roughing pump and as a backing pump, a diffusion pump, a ballast tank communicating with the high pressure outlet of said diffusion pump, conduit means connecting said exhaust socket with the low pressure inlet of said diffusion pump, secondary conduit means connecting said ballast tank with said mechanical vacuum pump, by-pass conduit means by passing said diffusion pump and ballast tank and connecting said exhaust socket directly with said mechanical vacuum pump, valve means for said conduit means, secondary conduit means and by-pass conduit means respectively, solenoid means for actuating said valve means, said solenoid means and valve means being constructed and arranged to maintain said valve means in said by-pass conduit in open position while maintaining said valve means in said conduit means and secondary conduit means in closed position whereby the diffusion pump is isolated from said mechanical pump and exhaust socket when said valve means in said by-pass conduit means is open and to maintain said valve means in said by-pass conduit means in closed position while maintaining said other valve means in open position whereby the diffusion pump is connected directly with said exhaust socket and is backed by said mechanical pump.

19. Automatically operating apparatus for evacuating vacuum tubes which contain metallic elements, said apparatus comprising, in combination, an endless track of substantial length, a plurality of cars adapted to move over the extent of said track, means for simultaneously moving said cars in succession over the extent of said endless track, each said car being adapted to carry a single tube to be evacuated, each said car carrying a complete vacuum pumping system for evacuating a single tube, each said vacuum pumping system comprising a mechanical vacuum pump, a diffusion vacuum pump, a ballast tank connected to the high pressure outlet of said diffusion vacuum pump, an exhaust socket adapted to engage a tube to be evacuated, and valve and conduit means arranged for connecting said exhaust socket directly to said mechani-

cal vacuum pump while isolating said diffusion pump and ballast tank from said pumping system during a portion of the travel of each said car along said track and for connecting said exhaust socket in series to the low pressure inlet of said diffusion pump and, through said diffusion pump, with said ballast tank and said mechanical pump during a subsequent portion of the travel of each said car along said track, means for actuating said vacuum pumps throughout movement of said cars along said track, individual inductance heating means on each of said cars arranged to inductively heat a tube being evacuated, means associated with a localized zone of said track for energizing said inductance heating means during movement of said cars along a portion of said track, energizing means on each said car adapted to be connected to the metallic elements of the tube carried by said car, means associated with a localized zone of said track for furnishing electrical current to said energizing means during movement of said cars along a portion of said track, and oven means positioned adjacent said track and being adapted to heat tubes being evacuated during travel of said cars along said track, said oven means extending along said track a distance substantially less than the extent of said track but substantially greater than and including the longitudinal extent of said localized zones in which said inductance heating means is energized and in which electrical current is furnished to said energizing means, said oven means including heating elements arranged to establish a temperature gradient longitudinally in said oven means.

20. A process for manufacturing vacuum tubes having a cathode and other metal elements therein, which process comprises simultaneously moving a plurality of tubes in succession along a path from a loading position to a seal-off position, independently evacuating each individual tube substantially throughout the movement of said tube from the loading position to and including the seal-off position, independently heating each tube by inductive heat while said tube is moving through a localized zone along said path, independently heating the cathode of each tube by energizing the cathode while said tube is moving through a localized zone along said path, heat-treating the tubes externally in accordance with a predetermined temperature gradient during movement of said tubes along a portion of said path substantially longer than and including said inductance heating and cathode heating zones, sealing off completely evacuated tubes at the seal-off position, removing the sealed tubes from the process, and thereafter replacing said tubes at the loading position with tubes to be processed as described.

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