Aug. 27, 1963 J. A. McCULLOUGH ET AL 3,102,180

APPARATUS FOR MAKING ELECTRON TUBES

Original Filed Dec. 5, 1957 3 Sheets-Sheet 1

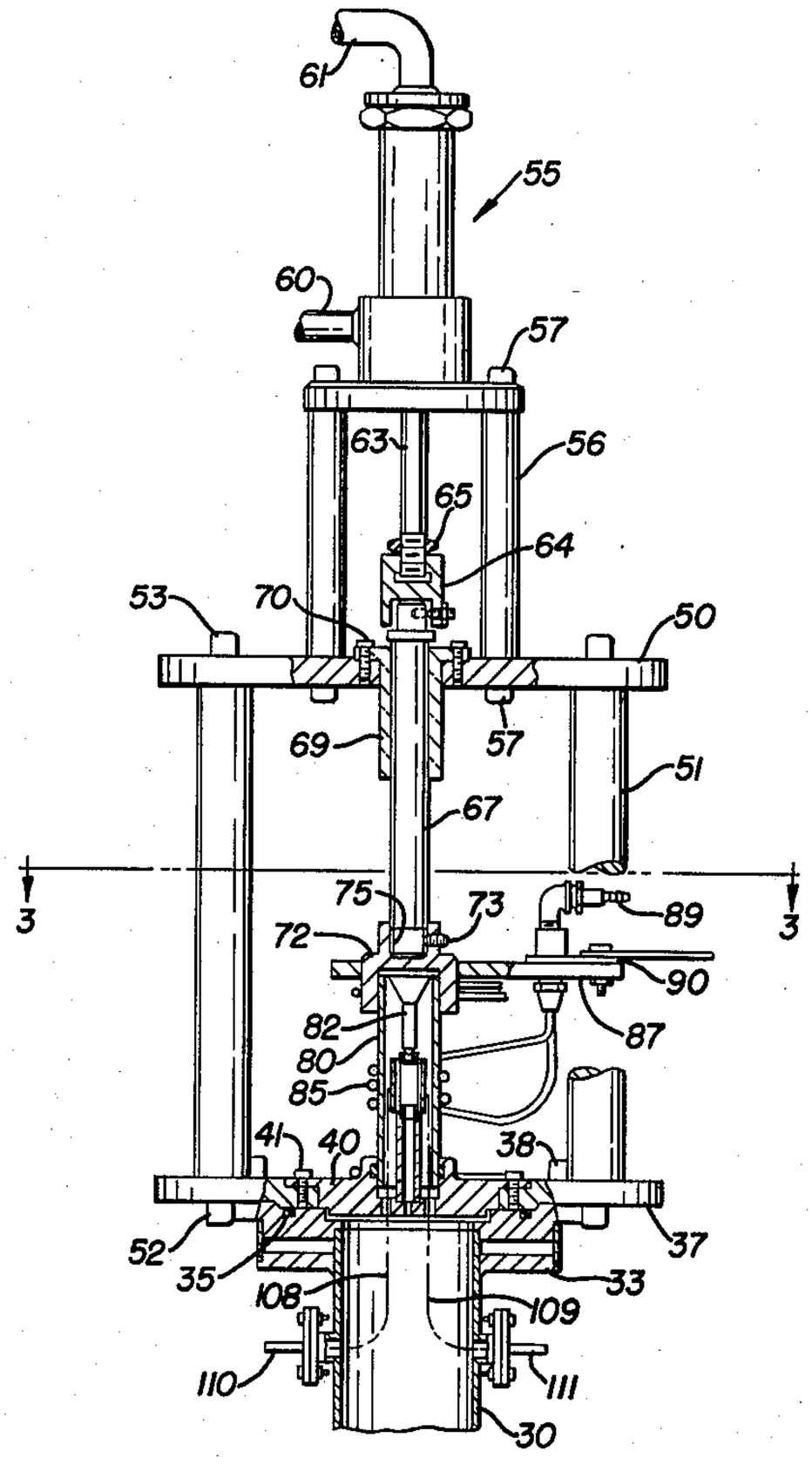

Fig. 1

INVENTORS
JACK A. McCULLOUGH
WILLIAM R. STUART
BY
Leon F. Herbert
Robert W. Dilts
ATTORNEYS

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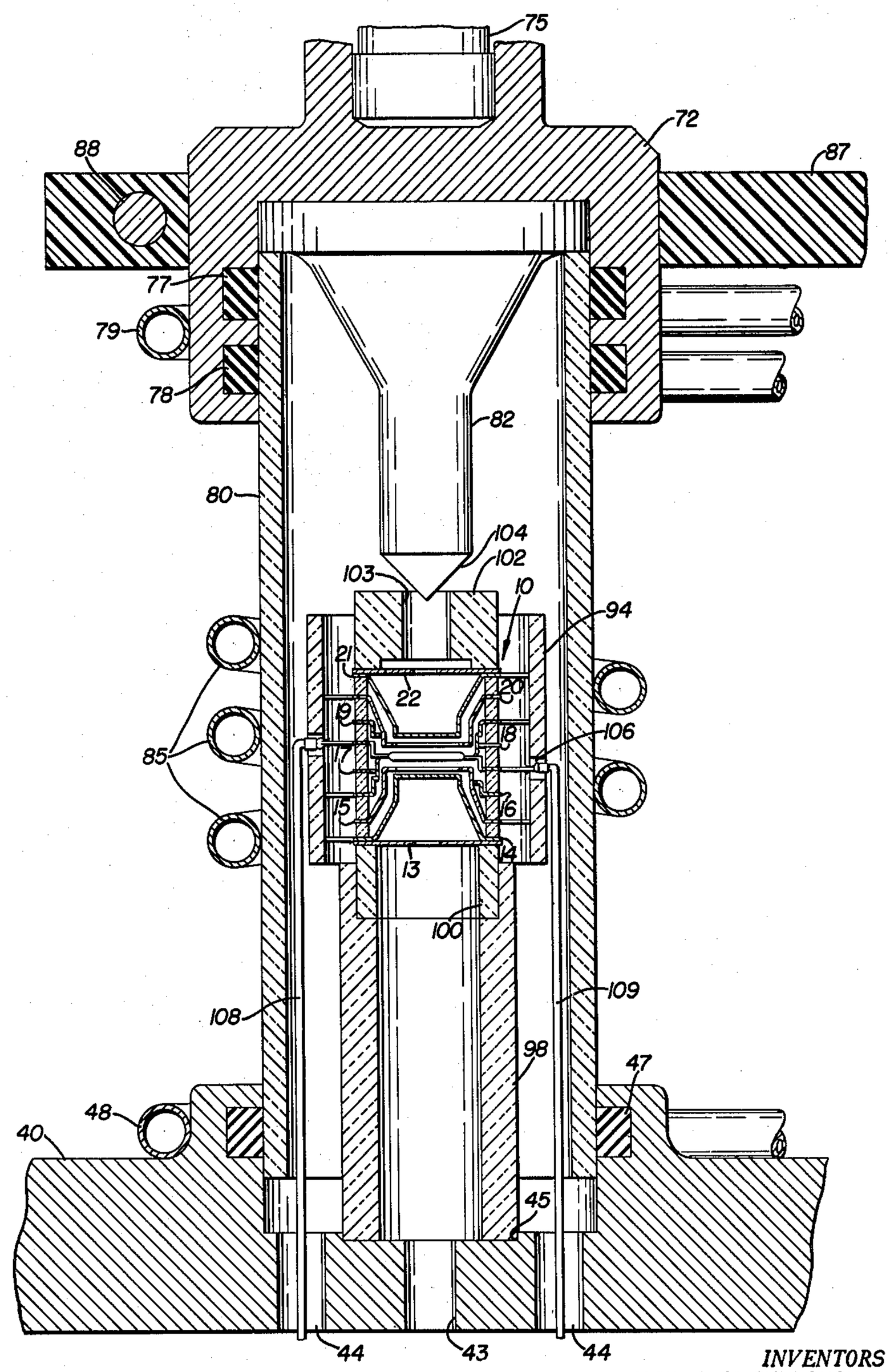

Fig. 2

INVENTORS
JACK A. McCULLOUGH
WILLIAM R. STUART

BY Leon F. Herbert
Robert W. Dilts
ATTORNEYS

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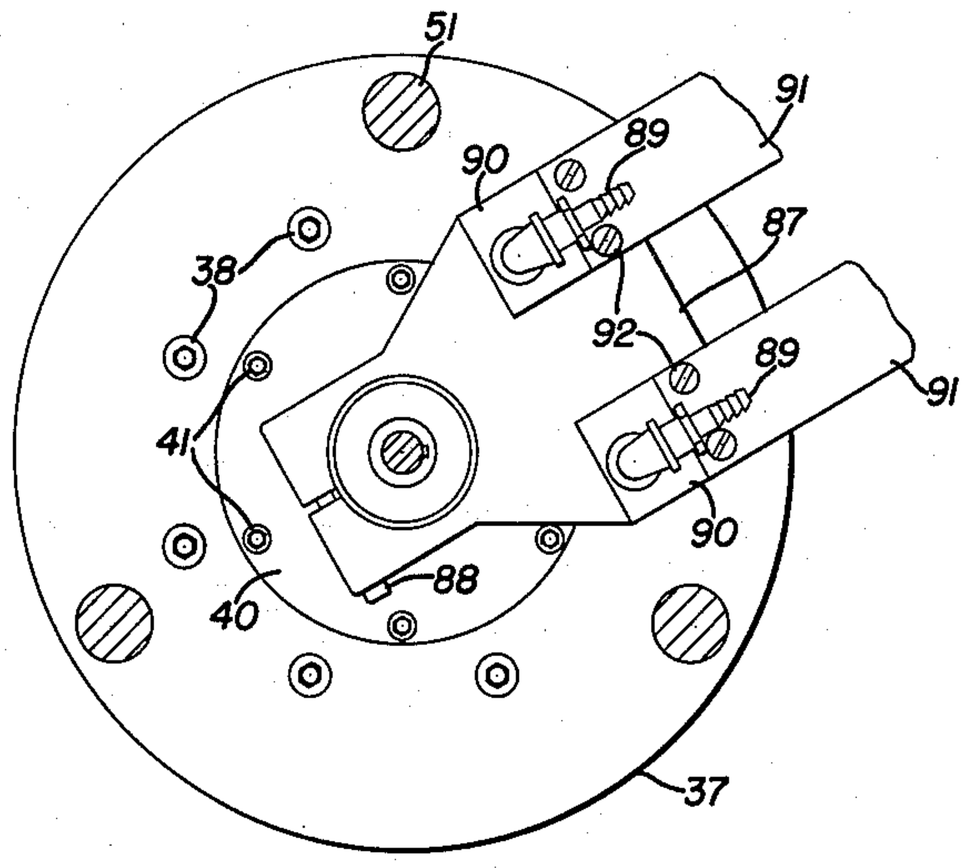

Fig. 3

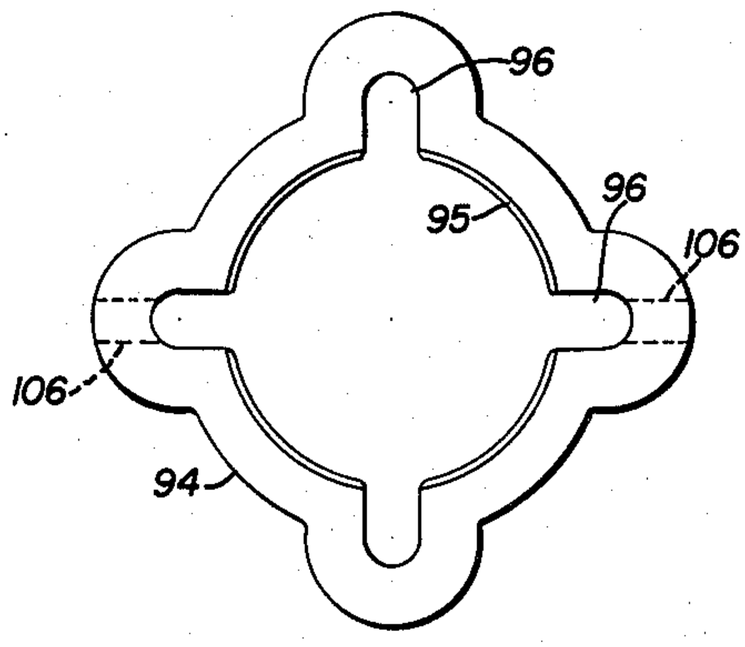

Fig. 4

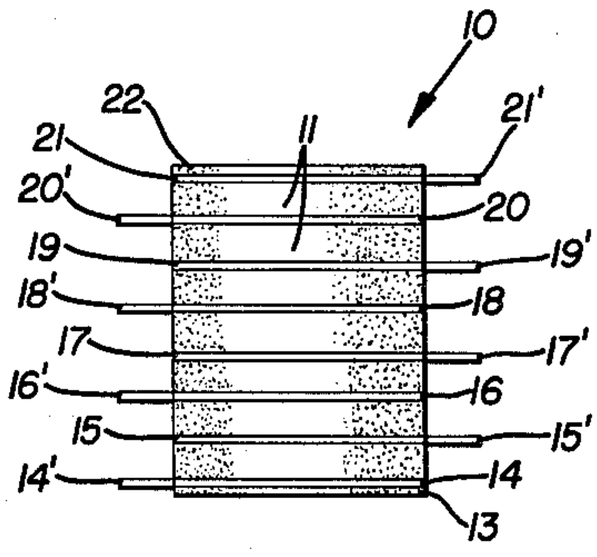

Fig. 5

INVENTORS
JACK A. McCULLOUGH
WILLIAM R. STUART
BY
Leon F. Herbert
Robert W. Dilts
ATTORNEYS

United States Patent Office

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APPARATUS FOR MAKING ELECTRON TUBES

Jack A. McCullough, Los Altos, and William R. Stuart, San Carlos, Calif., assignors to Eitel-McCullough, Inc., San Carlos, Calif., a corporation of California

Original application Dec. 5, 1957, Ser. No. 700,853, now Patent No. 2,996,347, dated Aug. 15, 1961. Divided and this application Sept. 29, 1960, Ser. No. 59,265

6 Claims. (Cl. 219—9.5)

This invention relates to apparatus for making electron tubes. More specifically, the invention relates to apparatus for making electron tubes having pressure seals made between two metallic surfaces. The term "pressure seal" is defined for use herein as a permanent, vacuum-tight seal obtained by the application of pressure at temperatures below the melting point of any of the metals within the seal or any of the materials around the seal. This invention is a divisional of our application Serial No. 700,853, filed December 5, 1957, now Patent No. 2,996,347, issued August 15, 1961.

The construction of electron tubes is such that practically all types have a shell or envelope involving at least two sections sealed together along an annular joint. In the past it has been standard practice to join envelope sections by means of fused or melted bonds, such as the conventional braze or weld joint. It has previously been proposed that a vacuum-tight seal could be made at temperatures below the melting point if the surfaces to be joined were given an optical polish. This optical polish technique has never been adopted commercially for a number of reasons including the fact that optical polishing is expensive.

The present invention has as a basic object the teaching of an apparatus by which electron tubes can be made with pressure seals on a commercially practical basis.

A more specific object of the invention is to provide a pressure sealing apparatus having a very short processing cycle. An associated object of the invention is to provide a pressure sealing apparatus in which heating of the seal is accomplished by inducing an R.F. current directly in the metal surfaces to be sealed together.

A further object of this invention is to provide a pressure sealing apparatus which does not involve the expense of obtaining an optical polish on the surfaces to be joined.

An additional object of the invention is to provide a pressure sealing apparatus which eliminates need for the usual exhaust tubulation on tubes. An associated object is to provide a pressure sealing apparatus which combines into a closely related system the formation of the pressure seal and the normal tube processing procedures such as exhaust, bakeout, and cathode formation.

Another object of the invention is to provide an electron tube having an envelope comprising two members joined together by a pressure seal.

In essence, the invention resides in the making of electron tube pressure seals by the application of high pressures and high temperatures in a vacuum. Although high temperatures are utilized, they are of course below the melting point of any of the materials involved in making the seal. The components of the apparatus remain relatively cool as the metallic sealing surfaces are elevated in temperature.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of the invention. It is to be understood that the invention is not limited to the disclosed species, as variant embodiments thereof are contemplated and may be adopted within the scope of the claims.

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Referring to the drawings:

FIGURE 1 is a side view partly in section showing a vacuum chamber and pressure exerting ram in accordance with the invention. An electron tube is shown in the chamber and the ram is positioned in pressure exerting contact therewith;

FIGURE 2 is a cross-sectional view showing the vacuum chamber of FIGURE 1 on an enlarged scale. The tube is shown in cross section, and the position of the ram is such that it is not exerting pressure on the tube;

FIGURE 3 is a view on line 3—3 of FIGURE 1;

FIGURE 4 is an enlarged top view of the tube holding jig of FIGURES 1 and 2; and

FIGURE 5 is a side view of a completed tube of the type shown in FIGURE 2.

Referring to the drawings in more detail, FIGURE 5 shows an example of a tube **10** made by the apparatus of the invention. The particular tube shown in the drawings is cylindrical in shape and has an envelope wall made of a plurality of ceramic rings **11** and a plurality of metal rings **13–22**. FIGURE 2 shows the tube **10** in cross-section, and the construction of the tube can be best understood by viewing both FIGURES 2 and 5. It will be noted that the tube is a double triode so that metal rings **14** and **21** both form anodes at the ends of the tube. Metal rings **15** and **20** form supports for control grids; rings **16** and **19** form cathode supports; and rings **17** and **18** form leads for the single heater which is inside the double cathode. The end rings **13** and **22** are merely to protect the anode rings against damage. Each of the electrode rings is provided with a terminal tab for which primed reference numerals are employed. The terminal tabs are arranged in two diametrically positioned rows.

Although a specific tube has been disclosed for convenience in describing the apparatus, it will be understood that other tube configurations can be made by the invention.

Coming now to the novel apparatus of the invention, FIGURE 1 discloses the stand pipe **30** of a conventional exhaust pumping system (not shown). At the upper end of pipe **30** a water cooled mounting disk **33** is attached as by brazing, and a sealing ring **35** is seated in a recess on the upper surface of the disk. A support ring **37** is attached to disk **33** by means of screws **38**. A base member or plate **40** is mounted in the center of support ring **37** by means of screws **41**. As shown best in FIGURE 2, the base plate **40** has a central aperture **43** and two side apertures **44**. In addition, the plate **40** has a central seating recess **45** and an annular recess in which sealing ring **47** is positioned. A coil of tubing **48** encircles plate **40** in the area of seal **47** to permit cooling of the seal.

A platform **50** is mounted on support ring **37** by means of three rods **51** which are attached to ring **37** by screws **52** and the platform **50** by screws **53**. In turn, platform **50** supports a conventional hydraulic cylinder and piston unit **55** by means of three rods **56** held in place by screws **57**. The cylinder and piston unit is connected by pipes **60** and **61** to a conventional hydraulic pumping system (not shown).

A piston rod **63** extends down from the unit **53** and is threaded into a coupling **64** and fixed by lock nut **65**. A rod **67** is accurately guided by a bushing **69** which is mounted on platform **50** by screws **70**. Rod **67** fits into coupling **64** with considerable play in order to accommodate any misalignment between bushing **69** and the piston rod **63**. A coupling **72** is mounted on the end of rod **67** where it is held in place by a screw **73** which engages a recessed wall portion **75** on rod **67**. The rod **67** has an accurately machined closed fit in coupling **72**, and

the recess 75 is provided so that the screw 73 will not roughen the accurately machined portion of the rod.

The lower end of coupling 72 has a recessed portion lined with two sealing rings 77 and 78 (FIGURE 2). A cooling tube 79 is attached to coupling 72 to prevent heating of the sealing rings. A glass cylinder 80 is held in the end of coupling 72 by frictional engagement with sealing rings 77 and 78. A ram 82 is held wedged between the recessed end of coupling 72 and the upper end of cylinder 80. Ram 82 is made of ceramic or other dielectric material having high strength and low heat conductivity.

A tubular coil 85 surrounds cylinder 80 about the center thereof. Radio frequency current is passed along the coil 85 and cooling water is passed therethrough. The coil is arranged to move up and down with the cylinder, as will now be described. A platform 87 of insulating material is split at one end and clamped to coupling 72 by means of screw 88. The ends of the coil 85 are attached to platform 87 to support the coil and are provided with fittings 89 for connection to flexible water hoses. The ends of coil 85 and the fitting are joined to metal plates 90 which are attached to platform 87 and to which flexible copper strap leads 91 are attached by screws 92 (FIGURE 3). The leads 91 are connected to a conventional source of radio frequency power (not shown).

The structure thus far described provides the operating mechanism for making a tube according to the invention. The remaining structure shown within the cylinder 80 in FIGURES 1 and 2 consists of the tube and the jigging for it. The tube 10 has already been described. It will be seen best in FIGURES 2 and 4 that the tube parts are loaded in a cylindrical jig 94 having a central bore 95 and longitudinal grooves 96. The grooves 96 must be at least equal in number to the number of rows of terminal tabs on the tube, assuming of course that the tube under construction has this type of terminal arrangement. It will be seen in FIGURE 4 that jig 94 has four grooves 96 whereas tube 10 has only two rows of terminal tabs. The two extra grooves are desirable for free passage of air from the tube to the exhaust chamber. Jig 94 is made of dielectric material such as ceramic.

The jig 94 is supposed on a cylindrical stand 98 which is received in the seating recess 45 in plate 40. A short elevating ring 100 is received in the upper end of stand 98. A pressure ring 102 rests on the top of the tube and is provided with a central bore 103. Ram 82 is provided with a tapered tip 104 which engages the rim of bore 103 to assure even application of pressure. Stand 98 and the rings 100 and 102 are made of ceramic or other dielectric material having high strength and low heat conductivity.

Jig 94 is provided with two apertures 106 opening into diametrically opposed recesses 96 so that electrical connection can be made to heater tabs 17′ and 18′. The connection is made by leads 108 and 109 which pass through aperture 44 in plate 40 and are connected to terminals 110 and 111 (FIGURE 1) which are mounted on but insulated from stand pipe 30. The upper ends of leads 108 and 109 are provided with contact fingers which pass through apertures 106 and engage tabs 18′ and 17′, respectively.

The method of using the hereinbefore described apparatus in the manufacture of a tube will now be explained. FIGURES 1 and 2 show a tube 10 positioned inside the vacuum-tight chamber formed by the base member 40 in cooperation with the wall structure comprising cylinder 80 and coupling 72. Naturally, the first step is to insert the tube parts into the vacuum chamber. Preferably the tube parts, such as parts 13–22, are loaded into the jig, such as jig 94, before placing the jig in the vacuum chamber. In practice it is desirable to assemble stand 98, ring 100, jig 94, the tube parts, and ring 102 outside the vacuum chamber and insert them as a unit. It will be apparent from FIGURE 1 that by operating the cylinder and piston unit 55 to raise piston rod 63, the glass cylinder 80 can thereby be lifted so that its bottom edge is above

the position of ring 102 to permit easy insertion of the tube and associated ceramic parts 98, 100, 94 and 102.

After the tube and associated ceramic parts have been placed in processing position with stand 98 seated in recess 45, the ends of heater leads 108 and 109 are inserted through slots 106 so that the contact fingers on the leads engage the heater terminals 118′ and 117′. Next, the cylinder and piston unit 55 is operated to lower the glass cylinder 80 until its lower end makes sealing contact with sealing ring 47 but before ram 82 makes contact with ring 102, as shown in FIGURE 2.

Next, the stand pipe 30 is connected, as by suitable valving, to a conventional vacuum system to obtain a vacuum in the cylinder 80 and hence within tube 10. At this point it should be explained that the separate metal and metallized ceramic envelope parts have sealing surfaces which are not provided with an optical finish. In fact, the sealing surfaces which are pressed together need not be polished at all, although coining to obtain flatness is desired.

In addition to saving the expense of optical polishing, the use of sealing surfaces which have a finish rougher than an optical finish permits the tube to be quickly and fully pumped in a vacuum chamber without resorting to some means for holding the sealing surfaces separated during pumping. It will be understood by those skilled in the art that if the sealing surfaces have an optical polish they will fit so closely together that the passage of gas therebetween will be at best so slow as to require an unreasonably long pumping period.

After connecting the vacuum chamber to the pumping system, the tube is heated and allowed to outgas for a period commensurate with its size. At this point it is desired to emphasize the fact that the heating is accomplished by inducing a radio frequency current directly into the metal portions of the tube. In addition to any beneficial effect the high frequency current may have in the action which causes the sealing surfaces to bond together upon the application of pressure, the direct induction of radio frequency current eliminates the prolonged heating and cooling period which would be required if a conventional oven type of heating were employed. In this connection it should be understood that one of the reasons for making parts 98, 100, 102, 82, and particularly jig 94 out of dielectric material is so that they will not prevent or diminish the induction of R.F. current in the metal parts of the tube. Similarly, it will be appreciated that the elimination of metal as the material for parts which are subject to high temperature makes it possible to raise cylinder 80 immediately after forming the pressure seals. If metal were used it would be necessary to have a cooling period within the vacuum, as otherwise oxides would form and destroy the tolerances for parts 98, 100, 102, 104 and particularly 94.

During the outgassing period any required cathode forming is accomplished. The particular tube shown in the drawings employs a conventional oxide coated cathode. Forming of the cathode is accomplished by applying power to the leads 108 and 109 which energizes the heater to the extent necessary to raise the cathode to forming temperature.

When forming of the cathode and outgassing has been completed, the next step is to make the pressure seals. The pressure seals are made by operating the cylinder and piston unit 55 to move piston rod 63 downwardly until ram 82 engages pressure ring 102 with sufficient force to apply to the sealing surfaces a unit pressure substantially in excess of that which would be provided by exposing the outside of the tube to atmospheric pressure with a vacuum on the inside. It should be understood that evacuation of the vacuum chamber and induction heating of the sealing surfaces are continued when the sealing pressure is applied. After the sealing pressure has been applied and a vacuum tight seal has been formed, the heating current in coil 85 is cut off, stand

pipe 30 is disconnected from the vacuum pump, cylinder 80 is raised, tube 10 and jig 94 are removed from the vacuum chamber, and finally the tube is removed from the jig.

Although the exact nature of the sealing action may not be known with provable certainty, it seems reasonably clear that the practical success of the pressure sealing method of this invention depends primarily on the fact that the metal surfaces to be sealed together are heated in a vacuum prior to the application of pressure and are not handled or removed from the vacuum between heating and the application of pressure. The point is that metal surfaces to be pressure sealed must be almost entirely free of dirt, occluded gases, oxides and other impurities. One of the best ways of accomplishing such cleaning is to heat the surface in a non-oxidizing environment, as for example in a vacuum or inert gas. Incidental to this understanding is the realization that the method of the invention can be used to make gas filled tubes employing one of the inert gases such as helium, or other gases such as hydrogen where the other gas does not form compounds with any of the particular metals out of which the sealing surfaces are made. Naturally, it is not only necessary that the metallic sealing surfaces be cleaned some time prior to the application of pressure, but they must also be kept clean between the cleaning step and the pressure step. The present invention provides the only practical method of maintaining cleanliness; namely, the method of pressing the metallic sealing surfaces together in the same chamber in which they were cleaned.

Perhaps in theory, perfectly smooth, perfectly clean metallic sealing surfaces would bond together in a vacuum tight seal without the application of any pressure. However, the purpose of the invention being to provide a practical mass production method of making electron tubes does not admit of such perfection. Thus, it is proposed that substantial pressure be used. One purpose of the pressure is to overcome the lack of smoothness. Clearly, if metallic sealing surfaces which are not perfectly smooth are brought together, they will not be in contact over their entire surfaces but only at a number of separate points. Although the points in contact may bond together to form a joint of appreciable strength, they will very likely not form a continuous wall, or vacuum tight seal. The invention requires, then, that enough pressure be applied to assure sufficient contact between the sealing surfaces to form a vacuum-tight seal. In addition, it has been found that the yield of good seals is increased if sufficient pressure is applied to actually cause radial deformation or extrusion of the metal in the sealing surfaces, or at least of the softer metal in the sealing surface where the surfaces are of different metals. This improvement is believed to be explainable by the theory that any surface oxides which might not have been removed by the high temperature cleaning can be broken up by deformation to expose clean metal. This theory also provides an additional reason for using metallic sealing surfaces having a finish which is rougher than an optical finish, the thought being that surface oxides can be more easily ruptured when relatively rough surfaces are pressed together than when optically smooth surfaces are used.

In connection with the application of pressure, it should be noted that the apparatus provides a very rapidly operating and simple arrangement. More specifically, the apparatus eliminates the need for complicated bellows arrangements by making the pressure exerting means or ram 82 movable with the chamber wall 80. Thus, the movement which initially closes the chamber places ram 82 almost in pressure exerting contact, and the movement which removes the pressure of ram 82 also opens the chamber so a finished tube can be immediately extracted. It is also important to note that when pressure is applied to the tube it is done with poor heat conductors such as

meramic pieces 98, 100, 102, and 82. There are two reasons for preventing a good heat conducting path; one is that it would be undesirable to drain heat from the sealing surfaces at the exact period of sealing, and the other reason is that sudden cooling of the tube ceramics would cause them to crack.

Utilizing the basic teachings of the invention, it is possible by experimentation to determine the minimum temperatures, pressures and duration of application which are necessary to obtain satisfactory seals between the various materials which might be used. By way of example, experiments have been made with tubes which comprise the following envelope construction: a high alumina ceramic member such as rings 11, a conventional molybdenum-manganese metalizing coating on the ceramic, and a nickel layer forming a sealing surface plated on the metalizing coating; a thin sealing ring of copper; and a metal envelope ring such as rings 13–22 of Kovar or nickel. The metalizing, the nickel plating, and the copper rings do not appear in the drawing because the invention is not limited to any specific materials and because they are extremely thin. For example, the copper ring is .003 inch thick and the metalizing and nickel plating are each only .0002 inch thick. Tubes having satisfactory seals with these materials have been made according to the following procedure utilizing the apparatus of the invention: Place the tube parts in the vacuum chamber, exhaust the chamber, induce R.F. current in the sealing surfaces for about three minutes to raise the temperature of the surfaces to about 750° C., lower ram 82 with sufficient force to deliver between 11,000 and 18,000 pounds per square inch pressure at the sealing surfaces, and maintain this pressure for about two and one-half minutes. The cathode must be formed prior to applying pressure and the earlier it is formed the longer will be the period for emptying the tube of the gases given off during forming.

Not only are the method and apparatus of the invention not limited to certain specific materials, they make it possible to effect pressure seals even using easily oxidized metals such as copper. The advantage of being able to use copper, which is a desirable metal in electron tubes, is made possible because the sealing surfaces are not removed from the non-oxidizing environment between the time they are cleaned by heating and the time they are pressed together.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus for making pressure seals, said apparatus comprising a base member having an exhaust aperture therethrough, said member having a circular recess on one side thereof into which said aperture opens, sealing ring means in the side wall of said recess, a cylinder coaxial with said recess, said cylinder having one end receivable in said recess in sliding contact with said sealing ring means, a closure member for the other end of said cylinder, said closure member having a recess in which said other end of the cylinder is received, sealing ring means in the side wall of said recess in the closure member, the last mentioned sealing ring means being in contact with said cylinder over a greater area than the area of contact between the cylinder and the first mentioned sealing ring means, means for moving said closure member toward and away from said base member, and a ceramic ram projecting from said closure member toward said base member inside said cylinder.

2. Apparatus for making pressure seals, said apparatus comprising a base member having an exhaust aperture therethrough, said member having a circular recess on one side thereof into which said aperture opens, sealing ring means in the side wall of said recess, a cylinder coaxial with said recess, said cylinder having one end receivable in said recess in sliding contact with said sealing ring means, a closure member for the other end of said cylinder, said closure member having a recess in which said

other end of the cylinder is received, sealing ring means in the side wall of said recess in the closure member, the last mentioned sealing ring means being in contact with said cylinder over a greater area than the area of contact between the cylinder and the first mentioned sealing ring means, and a ram positioned within said cylinder, said ram having a rim portion clamped between the end of said cylinder and the end of said recess in the closure chamber.

3. Apparatus for making pressure seals comprising a base member, a dielectric wall structure engageable with said base to form a vacuum chamber having an exhaust aperture therein, means for moving said wall structure toward and away from said base member, a sealing ring engaging said base member and the side of said wall structure and forming a vacuum tight seal between said base member and said wall structure during the terminal portion of said movement of the wall structure toward said base member, a ceramic ram positioned within said wall structure and movable therewith, and said ram and wall structure being so connected that any movement of said ram toward said base member is necessarily accompanied by movement of said wall structure toward said base member, and an induction heating coil surrounding said wall structure.

4. Apparatus as claimed in claim 3 in which said

means for moving the wall structure relative to said base member comprises an actuating unit having a cylinder element and a piston element, and connecting means joining said wall structure and ram to one of said actuating elements and joining said base member to the other of said actuating elements.

5. Apparatus as claimed in claim 3 further comprising a ceramic work supporting member seated on said base member and projecting toward said ram inside said wall structure.

6. Apparatus as claimed in claim 5 further comprising a cylindrical ceramic work holding jig mounted on said work supporting member.

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