June 11, 1957 L. J. CRONIN 2,795,033

MOLDED CATHODES

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FIG. 1

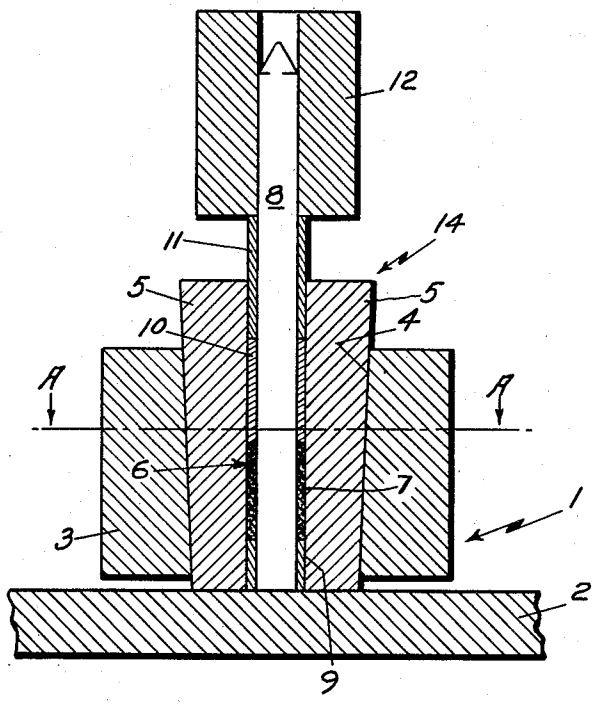
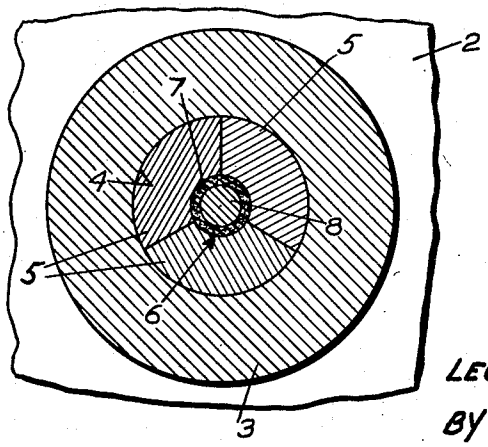


FIG. 2



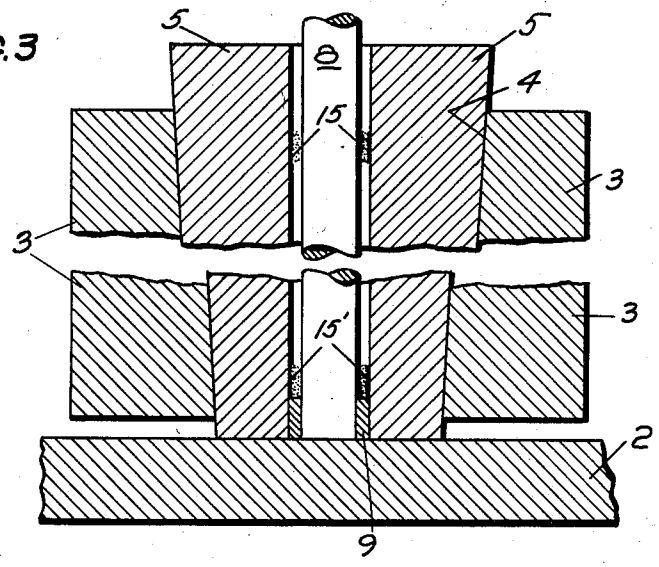
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MOLDED CATHODES

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FIG. 3



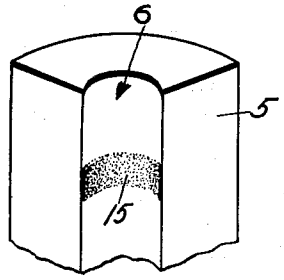
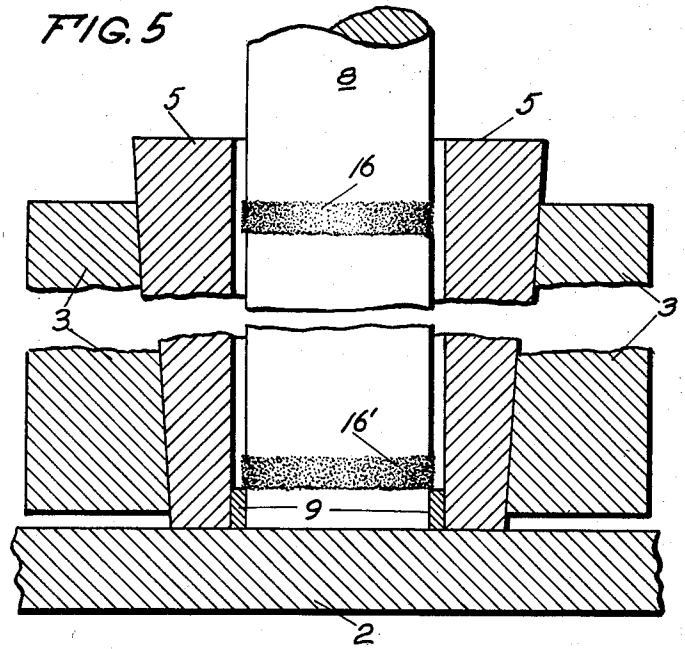


FIG. 4

FIG. 5



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FIG. 9

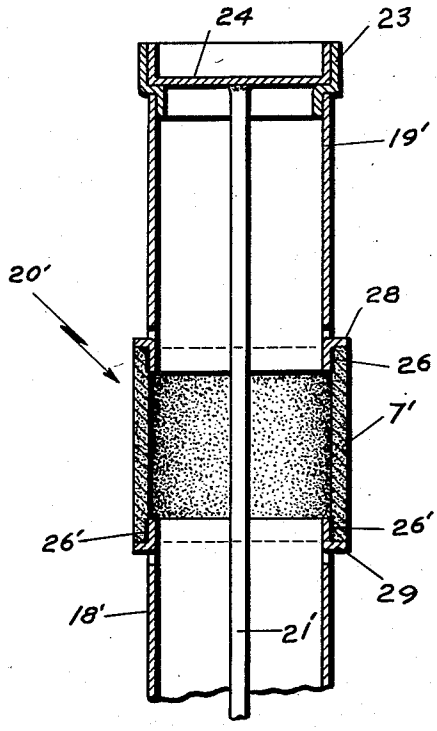


FIG. 10

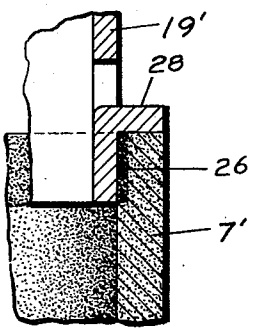


FIG. 11

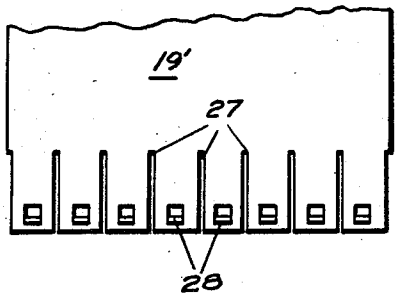
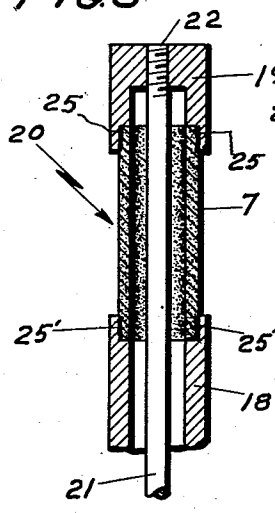


FIG. 8



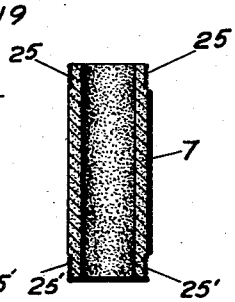


FIG. 6

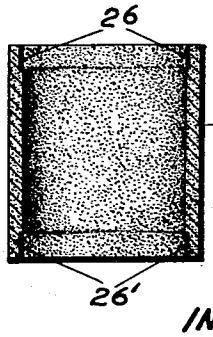


FIG. 7

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2,795,033

MOLDED CATHODES

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Application January 31, 1952, Serial No. 269,263

15 Claims. (Cl. 29—25.18)

This invention relates to a method for maufacturing molded cathodes and more particularly relates to a method for joining molded ceramic cathodes to metal supports.

The present method of joining molded ceramic cathodes, such as cathodes containing a substantial proportion of thoria, to metal supports involves the use of platinum solder. These soldered cathode assemblies are undesirable since platinum vaporizes at the cathode operating temperature of high powered tubes such as magnetrons and migrates over the cathode surfaces, thereby inhibiting the emission of electrons; moreover, platinum solder is very expensive. Other less expensive soldering alloys are unsatisfactory either because of their extremely low melting points or because of their inability to wet the ceramic cathode surface. Sintering of the metal supports directly to the ceramic cathodes is ineffective since a refractory metallic powder, such as molybdenum powder, alone will not adhere firmly to the ceramic cathode.

In accordance with the present invention, the inside of the mold in which the cathode is to be formed is coated with a thin layer of a powdered refractory metal suspended in a suitable binder. This coating is so applied to the mold that after the compacting operation it will be located in the form of a thin film or layer adjacent each end of the cathode at the proper distances from the active portion in the center. The ceramic compact is then removed from the mold and fired in a furnace containing a non-oxidizing atmosphere at a temperature in the range of approximately 1,800 degrees C. to 2,300 degrees C. for about one-half hour. At the conclusion of the firing, the refractory metal film becomes bonded tenaciously to the thoria compact. After machining these cathodes to size, they may be joined to metallic cathode supports which may or may not be of the same refractory metal as the metallic film or layer on the cathode. By molding the molybdenum powder into the body of the cathode in the manner just described, the cathodes may be firmly and economically joined to the metallic supports either by a conventional soldering or sintering process.

An object of this invention is to produce a firmly adherent layer of metal which is molded on the surface of molded ceramic cathodes.

A further object of this invention is to produce a ceramic to metal bond which can be easily produced and which will withstand considerable stress.

Still another object of this invention is to produce a ceramic cathode which may be readily and firmly joined to metal cathode supports by a conventional soldering or sintering operation.

Other and further advantages of this invention will be understood from the following exemplifications of the invention, reference being had to the accompanying drawings, wherein:

Fig. 1 is a longitudinal section view of a mold which may be used for making molded cathodes according to the present invention;

Fig. 2 is a transverse section view of the mold shown in Fig. 1 taken along line A—A of Fig. 1;

Fig. 3 is a fragmentary longitudinal section view of a portion of the mold of Fig. 1 illustrating the manner of applying a coating to the sleeve of said mold;

Fig. 4 is a fragmentary view of a portion of a coated sleeve segment of the mold shown in Figs. 1–3;

Fig. 5 is a view similar to Fig. 3 illustrating the manner in which the mold core is coated;

Fig. 6 is a section view illustrating one type of molded cathode;

Fig. 7 is a section view illustrating a second type of molded cathode;

Fig. 8 is a transverse section view of one modification of a cathode assembly;

Fig. 9 is a fragmentary longitudinal section view of a second modification of a cathode assembly;

Fig. 10 is a partial vertical section showing the details of Fig. 9; and

Fig. 11 is a development of one of the sheet metal supports shown in the assembly of Fig. 9.

Referring now to Figs. 1 and 2, a representative mold is shown for producing molded ceramic cathodes. A mold, generally indicated by the reference numeral **1**, rests upon a fixed support **2** and includes a cylindrical body **3** provided with a tapered bore **4** through which a plurality of sections **5** of a sectional sleeve **14** having an outer surface which follows the contour of bore **4** may be inserted. The segments **5** of the sleeve **14**, here shown as three in number, are assembled and fitted into bore **4** under pressure and the sectional sleeve defines a cylindrical bore **6**. A tubular bushing **9** is mounted on the lower end of the core **8** and said bushing and core are inserted into bore **6**. The annular space between the outer surface of core **8** and bore **6** is filled with a desired quantity of powdered ceramic material **7** capable of substantial thermionic emission, which may comprise, for example, a mixture of seventy-five percent powdered thoria and twenty-five percent powdered molybdenum. Bushings **10** and **11** are next placed over core **8** and a ram **12** positioned above core **8** as shown in Fig. 1. A pressure of about 200,000 pounds per square inch is applied to the upper surface of ram **12** so that the mixture **7** between bushings **9** and **10** is compacted. After removing the sleeve **14** from the mold body **3**, the sleeve is disassembled and the molded cylinder **7** formed from the compacted powdered mixture is removed. The molded cylinder must then be heat treated in a manner to be described later.

In Fig. 3 a sectional view of the mold of Fig. 1 is shown with certain parts removed in the interest of clarity. The inner surface **6** of sleeve **5** is coated with thin layers **15** and **15'** of a powdered refractory metal suspended in a suitable binder. For example, a paste made up of molybdenum powder held together by a solution of nitrocellulose in amyl acetate is applied to the surface **6** of sleeve segments **5**, as shown in Figs. 3 and 4. The three sleeve segments are assembled, the bushing **9** placed over core **8** and the bushing and core inserted into bore **6**. The powdered mixture containing thoria is poured into the mold to a level equal to the compression ratio times the desired length of the compacted cathode body. The areas over which the sleeve segments are coated depend in part upon the compression ratio of the material being molded. The portion of the cathode surface covered by the molybdenum film or coating should be large enough to provide satisfactory connections for the cathode support but not so large as to materially affect the emission of the cathode. The coating **15'** is positioned adjacent the top of bushing **9** and another coating **15** is applied adjacent the top surface of the powdered mixture in the mold. See Figs. 3 and 4. After the pressure operation is completed, layers or films **25** and **25'** of molybdenum will be molded into molded cathode **7**, as shown in Fig. 6. The compacted cathode

7, after removal from the mold, is next fired to give it mechanical strength and electrical conductance. The compacted cathode 7 is placed in a furnace containing an atmosphere of hydrogen or an atmosphere which is non-oxidizing in character and heated at approximately 1,800 degrees C. about one-half hour. A temperature range of from about 1,800 degrees C. to 2,300 degrees C. may be used for satisfactory results. The binder is driven off during heating and the molybdenum layers 25 and 25' become firmly molded into the body of the thoria cathode 7 at the ends thereof at the conclusion of the firing. These layers 25 and 25', being of metallic material, make possible the satisfactory jointure of said cathode to a metallic support at the region occupied by said layer.

One form of directly heated cathode assembly including the molded cathode of Fig. 6 is shown in Fig. 8 and comprises a cathode assembly, generally indicated by numeral 20, which includes an electron-emissive cathode in the form of the molded cylindrical sleeve 7 and adapted to be supported between an outer tubular electrically conducting member 18, made of a refractory electrically conductive material, such as molybdenum, and a cap or support 19, preferably made of the same material as support member 18. An inner conducting rod 21, mounted coaxial with outer conductor 18 and cathode 7, is threaded at one end 22 to receive conducting cap 19. The supports 18 and 19 are shouldered to support cathode 7. When a suitable voltage is applied between conductors 18 and 21, the current passing through cathode 7 heats the latter to the temperature of thermionic emission.

The portions 25 and 25' of the cathode 7 may be connected securely to cathode supports 19 and 18, respectively, either by sintering with a refractory metal powder, such as molybdenum powder, or by soldering with a solder having a high melting point, such as iridium and rhodium.

A second example of a directly heated cathode assembly, particularly suitable for electron discharge devices of the magnetron type, is shown in Fig. 9. An electron emissive cathode 7' is preferably constructed in the form of a cylindrical sleeve by compressing a mixture of powdered thoria (thorium oxide) and a powdered refractory metal, such as molybdenum, in a mold such as shown in Figs. 1 and 2 and in a manner to be described subsequently. A cylindrical sheet metal supporting sleeve 18', which may be constructed of molybdenum, is secured to the lower end of cathode 7' while a similar supporting sleeve 19' is likewise secured to the upper end of cathode 7'. Supporting sleeves 18' and 19' extend into opposite ends of cathode 7' a short distance sufficient to provide for rigid joints between the supports and the cathodes. The supporting sleeves may be stamped out of a thin sheet metal blank and bent into cylindrical shape. As shown in Fig. 11, the supporting sleeves may be provided with a plurality of longitudinal parallel rectangular slots 27 equally spaced around the periphery of the cylinder. Midway between adjacent pairs of rectangular slots 27 a plurality of spaced tabs 28 is formed by making three-sided cuts in support blank 19' and bending the sheet material outwardly at right angles to the plane of the blank, as shown in Figs. 10 and 11. Metallic sleeve 18' is formed in the same manner as upper sleeve 19'. As shown in Fig. 10, the lower surface of tabs 28 of upper sleeve 19' will engage the upper end surface of cathode 7'. Similarly, the upper surfaces of tabs 29 of lower sleeve 18' will engage the lower end surface of the cathode. Tabs 28 and 29 aid in positioning sleeves 19' and 18' relative to the cathode prior to jointure and aid in preventing motion of the cathode relative to the sleeves during the joining operation. The rectangular slots 27 make the ends of the supporting sleeves flexible to allow for the differential expansion of the cathode and its support and greatly reduce the relative movement between cathode and support and, consequently, the strain on the joint therebetween. It should be understood, however, that the rectangular slots and tabs may be eliminated and the cathode supports 18' and 19' made from a solid blank of sheet metal.

A metallic bushing 23 having a shoulder portion and preferably made of the same sheet metal stock as the supporting sleeves, is soldered to the upper end of sleeve 19', as shown in Fig. 9. A shallow disk 24 is placed inside bushing 23 with its lower face resting on and secured to the upper face of the bushing shoulder. A metallic conducting rod 21' is soldered or otherwise fastened to the bottom of disk 24. When a proper voltage is applied between support 18' and conducting rod 21', a current passes through cylindrical cathode 7', thereby heating the latter to the temperature of thermionic emission. If the thoria cathode sleeve is to be connected to a cathode support of the type shown in Figs. 9 and 10, it is obvious that, since the metallic supports are adapted to surround the cathode adjacent the ends thereof, the molybdenum films or layers 26 and 26' which are to be bonded to the thoria cathode should be located on the inner surface of the cathode. This type of molded cathode, as shown in Fig. 7, is formed in the same manner as the cathode of Fig. 6 except that the paste comprising the binder and molybdenum powder is applied to the core 8 of the mold, as shown at 16 and 16' in Fig. 5, rather than to the surfaces of the segments of the mold sleeve. The actual connection of the thoria cathode to the supports of Fig. 9 is accomplished in the same manner as in the case of the cathode assembly of Fig. 8.

It is also feasible to mold the cathode by exertion of lateral pressure, as, for example, by the hydro-static method. A rubber core may be used instead of a hard core 8 so that the core is distended sidewise or at right angles to the axis of the core. In this manner, the metalized paste may be applied over a more limited portion of the mold and the transfer of the metalized layer to the thoria compact will be more readily and definitely accomplished.

While two cathode assemblies are described and illustrated herein, it should be understood that other type cathode assemblies may be included within the scope of this invention. It is obviously possible to manufacture molded cathodes of various sizes and shapes, depending upon the configuration of the mold. Other methods of molding may also be used. Furthermore, the location and number of molded layers of refractory metal may be varied, depending upon the arrangement of and the number of connections to be made between cathode and cathode supports.

What is claimed is:

1. A method of manufacturing molded ceramic cathodes capable of being securely joined to metal supports comprising coating a portion of the inner periphery of a mold sleeve with a thin layer of powdered refractory metal suspended in a binder, inserting in said mold a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission, removing said refractory metal from said portion of said mold sleeve and compacting said powdered mixture and said refractory metal by exerting pressure on said mold to thereby form a molded cathode into the outer surface of which a layer of said refractory metal is molded.

2. A method of manufacturing molded thoria cathodes capable of being securely joined to metal supports comprising coating portions of a mold which are spaced a predetermined distance apart with a thin layer of powdered refractory metal suspended in a binder, inserting in said mold a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission, removing said refractory metal from said portions of said mold and compacting said mixture and said refractory metal by exerting pressure on said mold thereby forming a molded cathode into portions of whose

surface a layer of said refractory metal is molded, and firing said cathode until said metal layer is firmly bonded to said cathode.

3. A method of manufacturing molded ceramic cathodes capable of being securely joined to metal supports comprising coating portions of a mold which are spaced a predetermined distance apart with a thin layer of powdered refractory metal suspended in a binder, inserting in said mold a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission, removing said refractory metal from said portions of said mold and compacting said mixture and said refractory metal by exerting pressure on said mold thereby forming a molded cathode into portions of whose surface layers of said refractory metal are molded, removing said cathode from said mold, and firing said cathode at a temperature of at least 1,800 degrees C. until said metal layers are firmly bonded to said cathode.

4. A method of manufacturing molded ceramic cathodes capable of being securely joined to metal supports comprising coating portions of a mold which are spaced a predetermined distance apart with a thin layer of powdered refractory metal suspended in a binder, inserting in said mold a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission so that the top and bottom surfaces of said mixture coincide with said coated portions of said mold, removing said refractory metal from said portions of said mold and compacting said mixture and said refractory metal by exerting pressure on said mold thereby forming a molded cathode into which spaced layers of said refractory metal are molded, removing said cathode from said mold, and firing said cathode at a temperature of from approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layers are firmly bonded to said cathode.

5. A method of manufacturing molded ceramic cathodes capable of being securely joined to metal supports comprising coating a portion of the inner surface of a mold sleeve with a thin layer of powdered refractory metal suspended in a binder, inserting a core in the circular bore defined by said sleeve, inserting a desired quantity of a powdered mixture containing a substantial proportion of a ceramic capable of thermionic emission in the annular space between said sleeve and said core, compacting said mixture and said refractory metal so as to form a molded cathode into a portion of whose outer surface said refractory metal layer is molded, removing said cathode from said mold, and firing said cathode in an oxygen-free atmosphere at a temperature of approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layer is firmly bonded to said cathode.

6. A method of manufacturing molded ceramic cathodes capable of being securely joined to metal supports comprising coating a portion of the surface of a mold core with a thin layer of powdered refractory metal suspended in a binder, inserting said core in the circular bore of said mold defined by a mold sleeve, inserting a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission in the annular space between said sleeve and said core, compacting said mixture and said refractory metal so as to form a molded cathode into a portion of whose inner surface said refractory metal layer is molded, removing said cathode from said mold, and firing said cathode in an oxygen-free atmosphere at a temperature of approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layer is firmly bonded to said cathode.

7. A method of joining molded ceramic cathodes to metal supports comprising coating spaced portions of a mold with a thin layer of powdered refractory metal suspended in a binder, inserting a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission in said mold, removing said refractory metal from said portions of said mold and compacting said powdered mixture and said refractory metal by exerting pressure on said mold to thereby form a molded cathode into which spaced layers of said refractory metal are molded, removing said cathode from said mold, firing said cathode in an oxygen-free atmosphere at a temperature of from approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layers are firmly bonded to said cathode, and joining metallic cathode supports to said bonded metal layers on said cathode.

8. A method of joining molded ceramic cathodes to metal supports comprising coating portions of a mold with a thin layer of powdered refractory metal suspended in a binder, inserting a core in said mold, inserting a desired quantity of a powdered mixture containing a substantial proportion of a ceramic capable of thermionic emission in the space within the mold unoccupied by said core, compacting said mixture and said refractory metal so as to form a molded cathode into portions of whose surface said refractory metal layers are molded, removing said cathode from said mold, firing said cathode in an oxygen-free atmosphere at a temperature of from approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layers are firmly bonded to said cathode, and joining metallic cathode supports to said bonded metal layers on said cathode.

9. A method of joining molded thoria cathodes to metal supports comprising coating portions of a mold which are spaced a predetermined distance apart with a thin layer of powdered refractory metal suspended in a binder, inserting in said mold a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission so that the top and bottom surfaces of said mixture coincide with said coated portions of said mold, removing said refractory metal from said portion of said mold and compacting said mixture and said refractory metal by exerting pressure on said mold thereby forming a molded cathode into which spaced layers of said refractory metal are molded, removing said cathode from said mold, firing said cathode at a temperature of from approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layers are firmly bonded to said cathode, and joining a metallic cathode support to each of said bonded metal layers on said cathode.

10. A method of joining molded ceramic cathodes to metal supports comprising coating a portion of a mold with a thin layer of powdered refractory metal suspended in a binder, inserting a core in said mold, inserting a desired quantity of a powdered mixture containing a substantial proportion of a ceramic capable of thermionic emission in the space within the mold unoccupied by said core, compacting said mixture and said refractory metal layer so as to form a molded cathode into which said refractory metal layer is molded, removing said cathode from said mold, firing said cathode in an oxygen-free atmosphere at a temperature of from approximately 1,800 degrees C. to approximately 2,300 degrees C. until said metal layer is firmly bonded to said cathode, and sintering a metallic cathode support to said bonded metal layer on said cathode by means of a powdered refractory metal.

11. A method of joining molded thoria cathodes securely to metal supports comprising coating a portion of a mold with a thin layer of powdered refractory metal suspended in a binder, inserting a core in said mold, inserting a desired quantity of a powdered mixture containing a substantial proportion of a ceramic capable of thermionic emission in the space within the mold unoccupied by said core, compacting said mixture and said refractory metal layer so as to form a molded cathode into which said refractory metal layer is molded, removing said cathode from said mold, firing said cathode in an oxygen-free atmosphere at a temperature of from approximately 1,800 degrees C. to approximately 2,300

degrees C. until said metal layer is firmly bonded to said cathode, and soldering a metallic cathode support to said bonded metal layer on said cathode by means of a solder having a high melting point.

12. A method of joining molded thoria cathodes securely to molybdenum supports comprising coating portions of a mold which are spaced a predetermined distance apart with a thin coating of powdered molybdenum suspended in a suitable binder, inserting a desired quantity of a powdered mixture containing a large percentage of thoria in said mold, removing said molybdenum from said portion of said mold and compacting said thoria mixture and said molybdenum by exerting pressure on said mold thereby forming a molded thoria cathode at both ends of which a layer of said molybdenum is molded, removing said cathode from said mold, firing said cathode at a temperature of at least 1,800 degrees C. until said molybdenum layers are firmly bonded to said cathode, and sintering a molybdenum cathode structure to each of said molybdenum layers on said cathode with molybdenum powder.

13. A method of manufacturing hollow cylindrical molded ceramic cathodes capable of being securely joined to metal supports comprising coating a portion of the periphery of a mold core with a thin layer of powdered refractory metal suspended in a binder, inserting in said mold a desired quantity of comminuted mixture containing a large percentage of ceramic capable of thermionic emission, removing said refractory metal from said portion of said mold core and compacting said comminuted mixture and said refractory metal by exerting pressure on said mold to form thereby a molded cathode into the inner periphery of which a layer of said refractory metal is molded.

14. A method of manufacturing molded ceramic cathodes capable of being securely joined to metal supports comprising coating a portion of a mold with a thin layer of powdered refractory material suspended in a binder, inserting in said mold a desired quantity of a powdered mixture containing a large percentage of a ceramic capable of thermionic emission, removing said refractory metal from said portion of said mold and compacting said mixture and said refractory metal by exerting pressure on said mold thereby forming a molded cathode into whose surface a layer of said refractory metal is molded, and firing said cathode until said refractory metal layer is firmly bonded to said ceramic cathode.

15. A method of manufacturing molded ceramic objects capable of being securely joined to metal supports comprising coating a portion of a mold with a thin layer of powdered refractory material suspended in a binder, inserting in said mold a desired quantity of comminuted mixture containing a large percentage of a ceramic, removing said refractory metal from said mold and compacting said mixture and said refractory metal by exerting pressure on said mold thereby forming a molded cathode into portions of whose surface a stratum of said refractory metal is molded, removing said object from said mold, and firing said object at a temperature of at least 1,800 degrees C. until said stratum of refractory metal is firmly bonded to said ceramic cathode.

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