

United States Patent**Tsujimoto**[15] **3,701,915**[45] **Oct. 31, 1972**[54] **ELECTRON BEAM GUN**[72] Inventor: **Kazumi N. Tsujimoto**, El Cerrito, Calif.[73] Assignee: **Air Reduction Company Incorporated**, New York, N.Y.[22] Filed: **Jan. 4, 1971**[21] Appl. No.: **103,684**[52] U.S. Cl. **313/82, 219/121 EB, 313/70, 313/343**[51] Int. Cl. **H01j 29/46, H01j 1/00, H01j 29/56**[58] Field of Search. **313/70, 82, 343; 219/121 EB**

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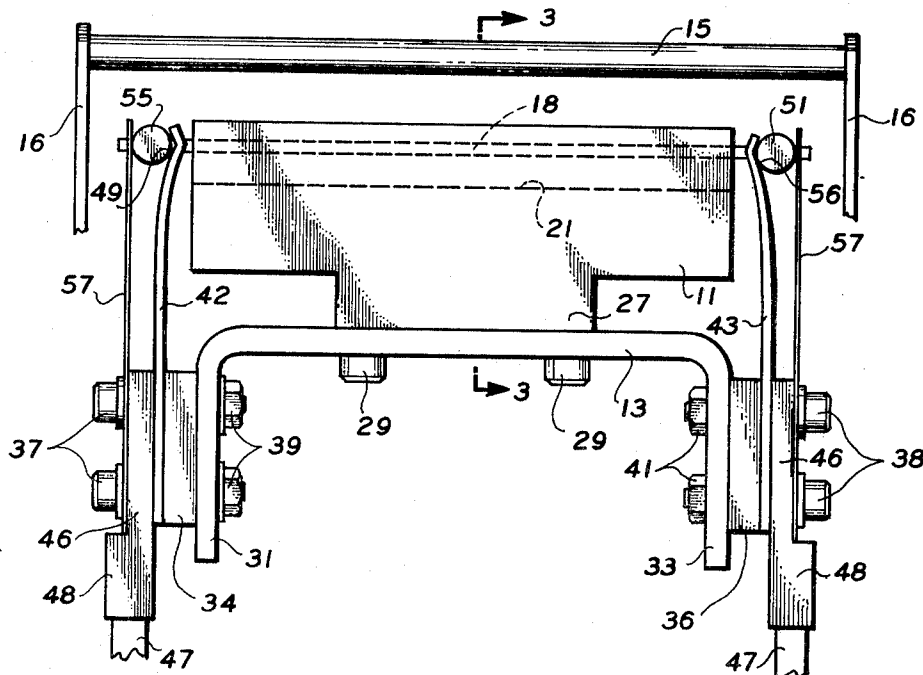
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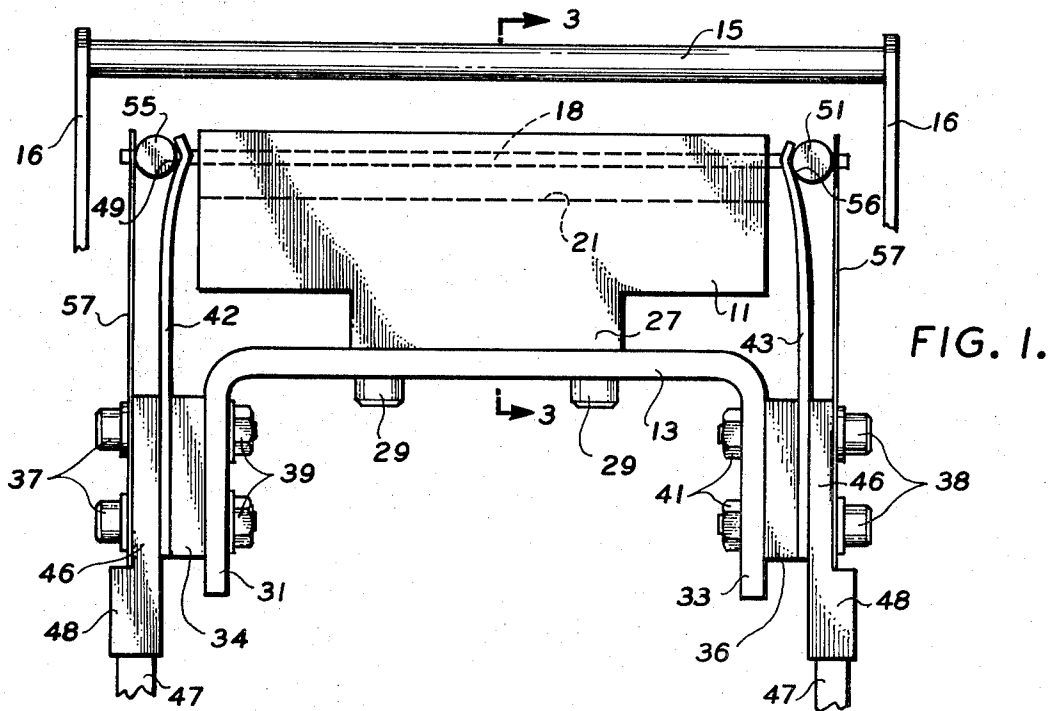
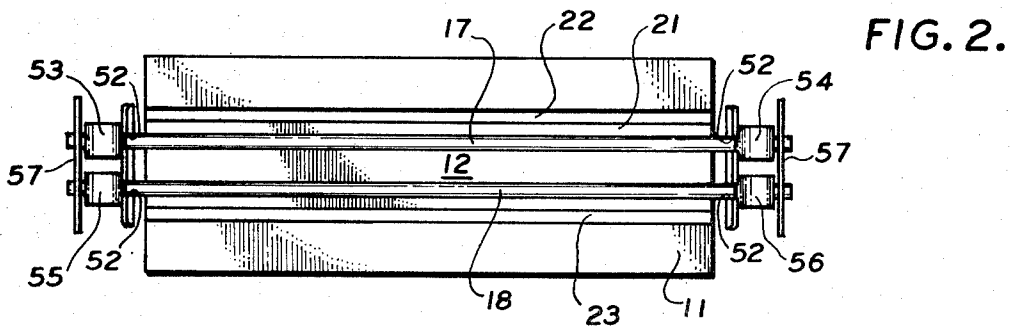
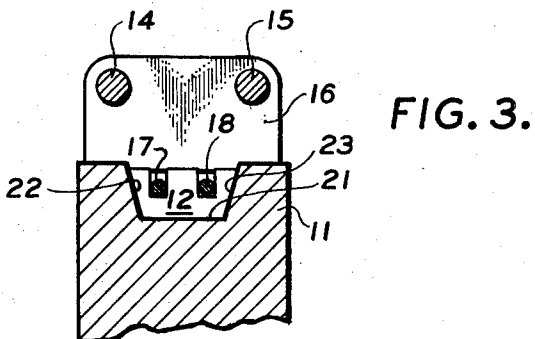
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[57]

ABSTRACT

An electron beam gun is described wherein a pair of elongated filaments are placed parallel to one another in the elongated channel of a focusing electrode.

3 Claims, 3 Drawing Figures



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ELECTRON BEAM GUN

This invention relates to electron beam guns such as are used in high vacuum electron beam furnaces. More particularly, the invention relates to an electron beam gun utilizing improved means for producing the electrons.

Electron beam furnaces have been used for some time in the vacuum processing of various materials. Such furnaces are utilized, for example, in the melting and casting of metallic ores to obtain relatively pure metals or alloys. Such furnaces are also used in the melting of materials other than metals, such as ceramics and plastics, and are frequently used to produce vapors of metals and other materials for deposition upon a substrate.

Electron beam furnaces utilize one or more electron beam guns for producing high energy electron beams. These beams are then directed in some manner to a target for heating the same. Electron beam guns generally comprise a heated electron source or emitter for emitting the electrons, and suitable means for generating a magnetic field for accelerating and focusing the electrons into a beam. The interior of the furnace is usually evacuated to a high degree and the electron beam gun is disposed at a convenient location within the vacuum chamber.

A particularly advantageous type of electron beam gun utilizes an elongated filament or emitter (of tungsten or other suitable material) disposed in an elongated channel in a backing or focusing electrode. The filament is heated to a thermionically emissive temperature and the backing electrode is maintained at a suitable negative potential in order to direct the electrons produced by the filament out of the open side of the channel. Suitable means may then be provided for accelerating and directing the electrons to a target. The beam produced is typically of a ribbon shape.

In electron beam furnaces, many ions may be produced as a result of vaporization of various materials in the furnace. The filaments or emitters of electron beam guns of the type described are susceptible to erosion as a result of bombardment by such ions. This is because positively charged ions may be attracted to the negatively charged backing electrode of the electron beam gun and thereby collide with the filament of the gun, producing erosion. The more frequently it becomes necessary to replace the filament of an electron beam gun, the more inefficient the apparatus in which it is incorporated becomes.

It is therefore an object of the present invention to provide an improved electron beam gun such as may be used in an electron beam furnace.

Another object of the invention is to provide an electron beam gun having long filament life.

Still another object of the invention is to provide an electron beam gun with less susceptibility to filament erosion due to ion bombardment.

Other objects of the invention and the various advantages thereof will become apparent to those skilled in the art from the following detailed description taken in connection with the accompanying drawings wherein:

FIG. 1 is a side elevational view of an electron beam gun constructed in accordance with the invention;

FIG. 2 is a top view of the electron beam gun of FIG. 1, with the upper elements removed; and

FIG. 3 is a partial sectional view taken along the line 3—3 of FIG. 1.

Very generally, the electron beam gun of the invention includes a focusing electrode 11 defining an elongated open-sided channel 12. Means 13 are provided for connecting the focusing electrode to a first source of potential. At least one accelerating electrode 14 or 15 is spaced from the open side of the channel defined by the focusing electrode. Means 16 are provided for connecting the accelerating electrode to a second source of potential which is substantially more positive than the first source. A pair of elongated filaments 17 and 18 are provided of thermionically emissive material. The filaments are supported parallel with each other and within the channel extending along the length thereof and spaced from the focusing electrode. The filaments may be connected to a source of heating current to raise them to thermionically emissive temperatures.

Referring now more particularly to the illustrated embodiment of the invention, it may be seen that the electron beam gun of the invention utilizes two parallel emitters or filaments 17 and 18. The emitters or filaments are each comprised of a thin tungsten wire, such as a wire of approximately 0.080-inch diameter. The filaments may be machined with opposite flattened surfaces, not shown, in which case the length of the flattened surfaces will correspond to the width of the ribbon beam it is desired to produce. Heating current conducted through the filaments causes emission of free electrons by the heated tungsten filaments in accordance with known phenomena.

The focusing electrode 11, which is maintained at a negative potential with respect to the accelerating electrodes subsequently described, is disposed immediately adjacent the two parallel filaments 17 and 18. The focusing electrode 11 is provided with the open-sided elongated channel 12 which, as may be seen from FIG. 3, comprises a generally flat bottom 21 and a pair of planar sides 22 and 23 extending therefrom and diverging from each other. The parallel filaments 17 and 18 are supported within the channel extending along the length thereof and are spaced from the focusing electrode 11. Preferably, the filaments are supported on opposite sides of the longitudinal axis plane of the channel, that is, a plane extending along the length of the channel perpendicular to the bottom 21 thereof and extending therefrom midway between the intersection of the bottom with the sides 22 and 23. The focusing electrode serves to cause the electrons emitted by the filaments to be directed out of the open side of the channel 12.

In order to accelerate the electrons moving out of the open side of the channel 12, the electron beam gun illustrated is provided with a pair of accelerating electrodes 14 and 15 in the form of a pair of parallel bars (not shown in FIG. 2). The accelerating anodes or bars 14 and 15 are supported between a pair of parallel connecting plates 16 which also serve as the means for connecting the accelerating electrodes to a source of potential which is substantially more positive than the source of potential to which the focusing electrode 11 is connected. As a result, electrons moving out of the open side of the channel 12 are accelerated into a beam of a generally ribbon shape. As an alternative, the

anodes may comprise screens or grids which produce accelerating fields but which permit the beam to pass therethrough, or the target itself may comprise an accelerating anode.

The focusing electrode 11 has a downwardly extending appendage 27 for supporting the focusing electrode. The appendage 27 is secured to a mounting plate 13 by means of mounting bolts 29 passed through suitable openings in the mounting plate and threaded into the appendage 27. The mounting plate 13 may also serve as the means for connecting the focusing electrode to a source of potential which is negative with respect to the accelerating electrodes 15 and 16. Further holes, not shown, may be provided in the mounting plate 28 to facilitate securing the mounting plate to a suitable mounting bracket, also not shown, in the electron beam furnace. Thus, the electron beam gun, depending upon the orientation and position of the unillustrated mounting bracket, may be disposed to direct the beam to almost any position in the electron beam furnace.

Opposite ends of the support plate 13 are each provided with a downwardly extending arm 31 and 33, respectively. The arms 31 and 33 are preferably made integral with the support plate 13. The downwardly extending arms 31 and 33 provide support for a pair of spacer blocks 34 and 36, to which the means which support the filaments or emitters are attached. The spacer blocks 34 and 36 are of electrically insulating material and are attached to the arms 31 and 33, respectively, by mounting bolts 37 and 38. The bolts 37 are secured by suitable nuts 39 and the bolts 38 are secured by suitable nuts 41.

Turning now to the means by which the emitters or filaments 17 and 18 are supported, two conductive members in the form of leaf springs 42 and 43 are secured to the spacer blocks 34 and 36 on the arms 31 and 33. Both of the leaf springs 42 and 43 extend from the spacer blocks 34 and 36 on the opposite sides of the focusing electrode 11 and terminate near the ends of the filaments 17 and 18.

The leaf springs 42 and 43 are made of electrically conductive material in order to conduct heating current to the emitters supported thereby, explained subsequently. This heating current is conducted to the leaf springs by a plurality of suitable electrical connectors 46 and conductive cables 47 connected thereto. The electrical connectors are bolted in contact with the corresponding leaf springs by means of the same bolts which secure the leaf springs against the spacer blocks 34 and 36. Each of the electrical connectors is provided with a socket 48 in which one end of the cable associated therewith is received.

The ends of the leaf springs 42 and 43 nearest the focusing electrode 11 are provided with recesses 49 and 51 therein. These recesses are formed in the leaf springs, such as by hot stamping, and each recess comprises a pair of intersecting planar surfaces. Thus, each recess has a roughly V-shaped cross section. Two parallel slots 52 are provided in the ends of each of the leaf springs. Each slot extends past the apex or intersection line of the planar surfaces comprising the recess and is of a size sufficient to permit the filament or emitter associated therewith to pass through the slot to the opposite side of the leaf spring.

Cylindrical contact elements 53, 54, 55, and 56, respectively, are secured to each end of each of the filaments or emitters 17 and 18. All the contact elements are electrically conductive and are provided with suitable holes therein through which the associated emitter passes. The contact elements are secured to the emitter by suitable means such as a shrink fit, welding, soldering, etc. The contact elements have curved surfaces which mate with the corresponding recesses in the ends of the leaf springs. Alternatively, a construction may be used wherein the surfaces of the elements have V-shaped protrusions which mate with the corresponding recess. In either case, good contact exists between each leaf spring and the contact element in engagement therewith. As may be seen in FIG. 1, the center line of the emitters is preferably on a radius of the curved surface of the contact elements.

Although the illustrated embodiment utilizes cylindrical contact elements which mate with V-shaped recesses, this configuration is not critical. For example, where the contact elements are cylindrical in shape as shown, the recesses may be formed to have corresponding cylindrical surfaces. The basic consideration is to provide a mating configuration which establishes satisfactory electrical contact between the emitter and the conductive springs, and which provides sufficient support for the emitter as explained in detail subsequently. Also, where the emitters are provided with flat surfaces to increase the surface presented to the direction the beam is to travel, the configuration should facilitate alignment of the flat area of the emitters with respect to the rest of the gun.

A pair of guard straps 57 are provided at the ends of the emitters 17 and 18. The guard straps are attached to the respective electrical connectors 46 on the opposite sides thereof from the respective leaf springs. The guard straps 57 are preferably of conductive material and are provided with holes therein near the ends of the guard straps close to the emitters such that the ends of the emitters projecting beyond the contact elements extend through the holes. This ensures that the emitter will not fall and short to ground in the event it breaks.

The filaments or emitters, being thin tungsten wires, are easily flexed or bent. This fact makes it important that the emitters be maintained under a slightly taut condition to ensure that the spacing between the emitters and the focusing electrode is constant for a constant electron beam configuration. In order to accomplish this, the leaf springs are biased outwardly of each other an amount which applies tension on each of the emitters which is sufficient to maintain the emitter taut but which is below the yield point of the emitter material at operating temperatures. Thus, the emitter will not be damaged or pulled apart due to excessive tension. The particular configuration of the invention enables the proper tension to be readily achieved by balancing spring bias while at the same time provides adequate electrical contact for conducting heating current through the emitter. Satisfactory results have been achieved in apparatus of the illustrated type using tensions in the range of 220 to 400 grams at operating temperatures of 2,200°C to 2,300°C.

As previously mentioned, normal electron beam furnace operation generally necessitates occasional

replacement of the emitters of electron beam guns. A simple manual pressure on the leaf springs supporting the emitter will relieve the outward bias of the leaf springs sufficiently to permit removal of the emitter. When the manual compression on the springs is released, the bias of the springs will position the emitter and support it as above described. In the event one of the filaments is longer than the others, a slight manual twisting may be imparted to the leaf springs 17 or 18 to permanently deform the springs and take up whatever difference in length is necessary. Alternatively, two separate pairs of supporting leaf springs may be utilized to support the respective filaments.

Because of the natural focusing tendency of the electrostatic field established by the focusing electrode 11, ions moving into the elongated channel 12 through the open sides thereof are focused and directed to pass between the parallel filaments 17 and 18. The ions therefore hit harmlessly in the bottom of the channel and do not strike either of the filaments to cause erosion. Thus, a substantial improvement in filament life is effected. Naturally, with the additional filament, greater beam power may also be provided since there is more emissive surface available to produce electrons.

A natural redundancy is also provided by the electron beam gun of the invention. Even though ion bombardment is minimized, there is a natural tendency for the filament to neck down or become smaller with the loss of electrons over the period of their operating life. As one of the filaments begins to neck down, however, its electrical resistance goes up and more current is therefore shunted to the neighboring filament, resulting in a natural correction and even life for both filaments.

A further advantage provided by the invention is that a more uniform energy density beam is produced without a substantial increase in the cross sectional size of the beam over that which would be produced by a single filament gun. The particular advantage of this feature is that of overcoming problems in evaporation within an electron beam furnace due to localized high energy density at the target which leads to spitting and localized high pressures. The more uniform energy density of the beam minimizes this possibility.

The depth within the channel 12 which the filaments 17 and 18 are placed, and the spacing between the filaments and the spacing between the focusing electrode 11 and the accelerating electrodes 14 and 15 are all generally interdependent. Moving filaments deeper into the channel reduces the perveance of the gun and decreases the thickness of the ribbon beam. Moving the

filaments further out toward the open side of the channel results in an increase of the beam thickness, the latter being limited to a thickness less than that which would cause the electrons to strike the accelerating electrodes. One satisfactory design utilizes an anode to anode spacing of 1 inch center to center, an anode to cathode spacing of 0.450 inch, a filament depth of 0.145 inch, a filament to filament separation of three sixteenths inch, a channel depth of one-quarter inch with an average channel width equal to its depth. Such a gun produces a broad beam at 30 KV anode to cathode potential.

It may therefore be seen that the invention provides an improved electron beam gun of substantially increased filament life. The gun is designed to prevent excessive ion bombardment of the filaments and produces a beam of more uniform energy density than is the case with a single filament gun.

Various modifications of the invention will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. In an electron beam furnace, an electron beam gun comprising, a focusing electrode defining an elongated open-sided channel, means for connecting said electrode to a first source of potential, at least one accelerating electrode spaced from the open side of said channel defined by said focusing electrode, means for connecting said accelerating electrode to a second source of potential which is substantially more positive than said first source, a pair of elongated filaments of thermionically emissive material, means for supporting said filaments parallel with each other within said channel extending along the length thereof and spaced from said focusing electrode, said filaments being positioned on opposite sides of the longitudinal axis plane of said channel with the space between said filaments being unobstructed, and means for connecting said filaments to a source of heating current.

2. An electron beam gun according to claim 1 wherein said focusing electrode is a solid body with said channel comprising an elongated recess in a surface thereof.

3. An electron beam gun according to claim 1 wherein said channel is comprised of a generally flat bottom and a pair of planar sides extending therefrom and diverging from each other.

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