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T. K. CAULEY

3,244,855

SYSTEM FOR CORRECTING THE SHIFT OF AN ELECTRON-GUN
BEAM FROM THE DESIRED REGION OF IMPINGEMENT

Filed July 19, 1963

2 Sheets-Sheet 1

FIG. 1.

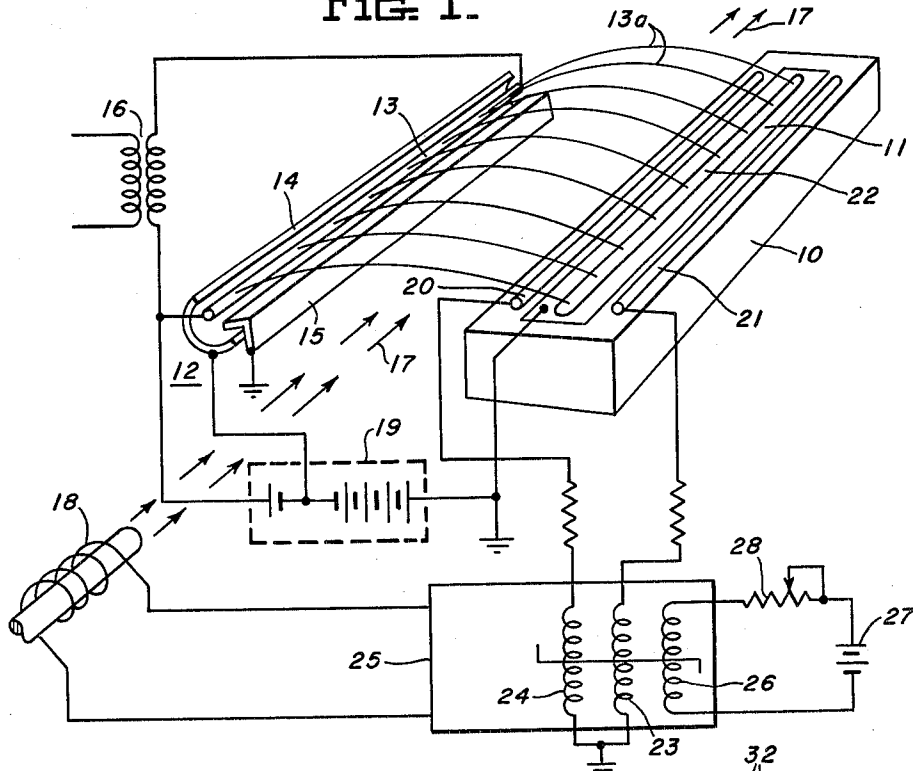
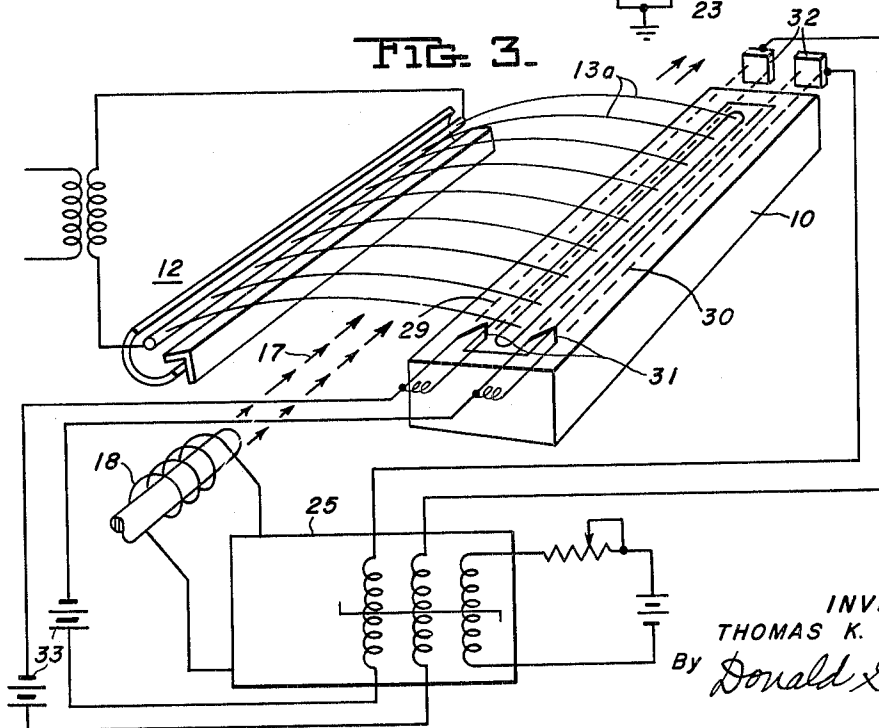


FIG. 3.

INVENTOR.
THOMAS K. CAULEYBy *Donald G. Dalton*

Attorney

April 5, 1966

T. K. CAULEY

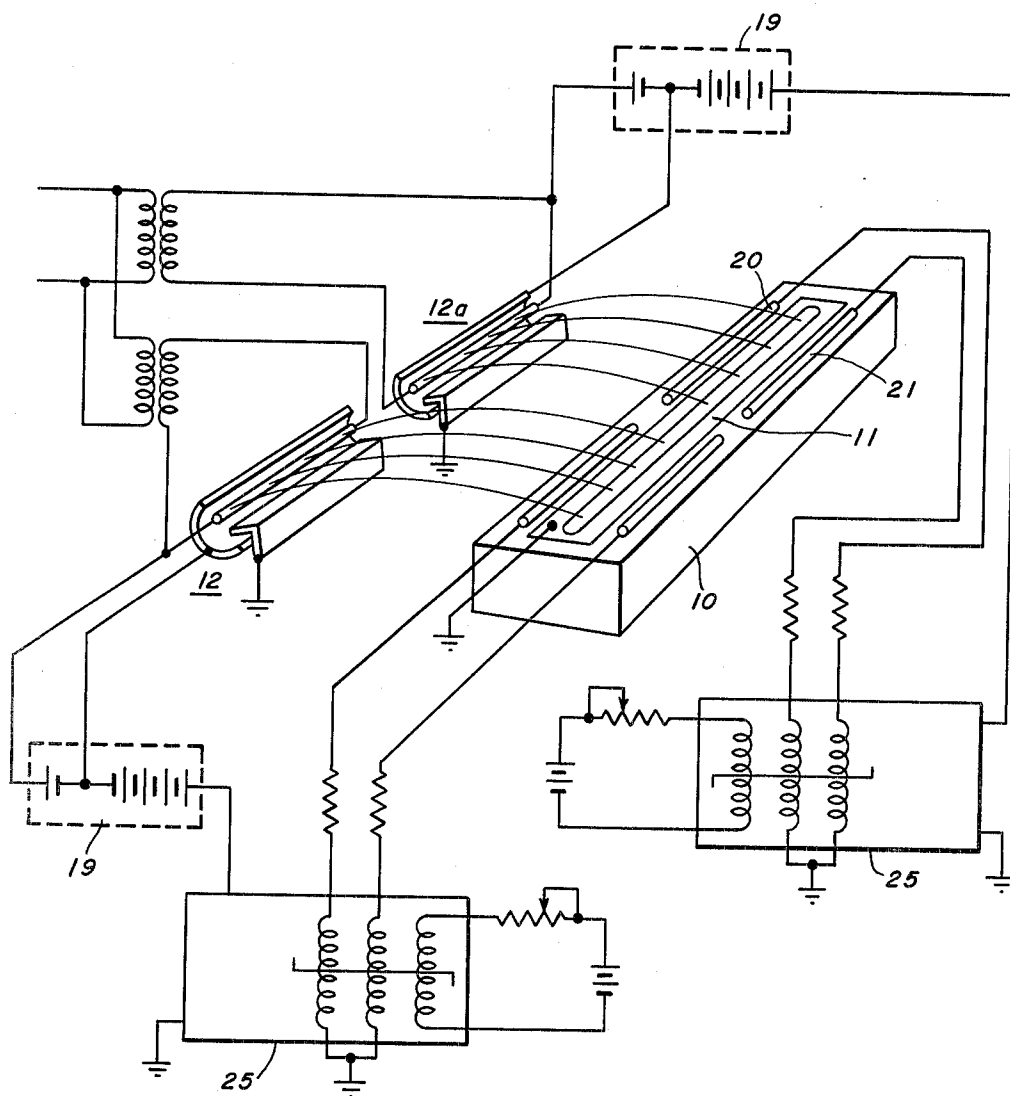
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FIG. 2.



INVENTOR.
THOMAS K. CAULEY
By *Donald L. Dalton*
Attorney

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SYSTEM FOR CORRECTING THE SHIFT OF AN ELECTRON-GUN BEAM FROM THE DESIRED REGION OF IMPINGEMENT

Thomas K. Cauley, West Mifflin Borough, Pa., assignor to United States Steel Corporation, a corporation of New Jersey

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1 Claim. (Cl. 219—121)

This invention relates to a system for correcting the tendency of a beam of electrons from a so-called electron gun, to wander from the desired area of impingement.

Electron-beam guns have found extensive use in industry for surface heating by bombardment. One instance is the art of coating with metal by vapor deposition in a vacuum, where the beam from the gun is directed onto the surface of a mass of coating metal to vaporize it. In the continuous coating of strip by this method, the crucible used to hold the coating metal, e.g., aluminum, is disposed transversely of the path of the strip in order to cover the entire strip width. This means that the crucible must be narrow or the mass of coating metal will be excessive.

In heating the surface of an elongated narrow crucible by electron bombardment, it is important to keep the electron beam constantly in close alignment with the center line of the crucible, both to assure efficient heating and to prevent damage to the crucible. The source of the beam is usually a filamentary cathode and the beam is therefore wide in the direction of the cathode length but is concentrated by shielding to a small dimension in the direction normal to the cathode. The source is usually on one side of the crucible and the beam is bent by a transverse magnetic field or an accelerating voltage so it will curve downwardly onto the metal in the crucible, as shown in Simons, Jr., United States Patent No. 3,046,936.

The object of my invention is to provide a system for controlling the magnetic field or the accelerating voltage so that the curvature imparted to the beam will be such as to cause impingement of electrons principally along the center line of the crucible and the mass of metal contained in the recess or cavity therein. In a preferred embodiment, I employ elongated sensing electrodes extending along each side of the crucible cavity so they will be subject to the impingence of electrons should the beam wander from the desired condition of alignment with the cavity. I provide means responsive to the resulting current in the sensing electrodes for varying the magnetic field or accelerating potential so as to increase or decrease the curvature of the beam to bring its area of impingence back to its normal position along the center line of the mass of metal in the crucible.

A complete understanding of the invention may be obtained from the following detailed description and explanation which refer to the accompanying drawings illustrating the present preferred embodiment. In the drawings:

FIGURE 1 is a diagrammatic showing of the invention incorporating a known arrangement of crucible and an electron gun for heating the metal therein; and

FIGURES 2 and 3 are similar diagrams showing modifications.

Referring now in detail to the drawings and, for the moment, to FIGURE 1 particularly, an elongated crucible 10 of refractory material, such as boron nitride, has a recess or cavity in its top face adapted to contain a charge of metal 11, such as aluminum, to be vaporized and deposited on a strip (not shown) passing above the crucible in a direction normal thereto. An electron gun 12 extends along the crucible on one side thereof. It com-

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prises a tungsten-filament cathode 13 extending between suitable supports (not shown), a focussing electrode 14 and a grounded accelerating anode 15.

A transformer 16 furnishes heating current to cathode 13. Crucible 10 is grounded as is also the anode 15. Cathode 13 is maintained at a negative voltage of, say 10,000 volts, and electrode 14 at a somewhat greater negative voltage by connections as shown to a direct-current source 19. The metal charge 11 in crucible 10 is the main anode toward which electrons from the cathode flow. The curvature of their paths indicated at 13a depends on the voltage applied to cathode 13 and the intensity of a magnetic field indicated at 17 between the poles of an electromagnet 18. The apparatus described above is conventional and is disposed within a suitable enclosure (not shown) evacuated to a high degree, i.e., to a pressure less than 30 microns.

In carrying out my invention, I provide crucible 10 with parallel sensing electrodes 20 and 21 extending therealong, one on each side of the recess or cavity therein containing charge 11. In the event of displacement of electron beam 13a for any reason, from the desired area of impingence on charge 11, indicated at 22, electrons will collect on one or the other of electrodes 20 and 21. These electrodes are connected to the control windings 23 and 24, respectively, of a magnetic amplifier 25 of known type such as the Norbatrol Electronic Corporation's Linear Power controller model 104C101, having a bias winding 26 thereon connected to a direct-current source 27. The output of amplifier 25, as modulated by current from electrodes 20 and 21 through windings 23 and 24, is applied to the winding of electromagnet 18.

A bias current applied to winding 26 of amplifier 25 is provided by source 27 under the control of an adjustable bias resistor 28 to set the nominal value of magnetizing-current output from the amplifier. Resistor 28 is adjusted so that the electron beam impinges on charge 11 centrally between the electrodes 20 and 21 when the control windings 23 and 24 are carrying equal currents. If, for any reason, the beam should wander toward one of the electrodes 20, 21, the resulting current in such electrode will produce a control current adding to or subtracting from the nominal value of the magnetizing current and move the beam away from that sensing electrode and toward the other. In this manner, the magnetic field is controlled so as to center and aline the electron beam with area 22.

The embodiment of FIGURE 1 uses a single electron gun and magnetic field. For long crucibles, it may be necessary to use several guns disposed end-to-end along the crucible length. With this arrangement, the several electron beams cannot be individually regulated by varying the intensity of the magnetic field, because this would affect the electron beams from all the guns. Effective control can be obtained, however, by regulating the accelerating potential of each gun on the basis of signals indicating the extent and direction of the wandering of its electron beam from the desired area of impingence. An arrangement suitable for this purpose is shown in FIGURE 2. For purposes of description, I have shown therein two magnetic amplifiers 25, each one controlling one of the high-voltage sources 19 to vary the accelerating effects of the cathodes 13 of their electron-beam guns 12 and 12a, respectively.

It may be noted that the sensing electrodes 20 and 21 will be subjected to vapor deposition from charge 11 as well as intense heating. Preferably, therefore, they should be made from a refractory metal, such as tungsten, and supported in any convenient manner to prevent their sagging.

Another embodiment of my invention is shown in FIGURE 3 including means for establishing two low-current

electron beams 29 and 30 between cathodes 31 and anodes 32. These beams replace the tungsten electrodes 20 and 21. Electrons are emitted from hot cathodes 31 and are accelerated by suitable voltage sources 33, along paths 29 and 30 parallel to the crucible, to anodes 32. The line of travel of each of these secondary electron beams is located substantially where one of the sensing electrodes 20 and 21 would be placed. When the main beam 13a of charge-heating electrons is diverted by any means to cross the path of the secondary electron beams, the space charge which the main beam produces in the path of the secondary beam, lowers the current carried in the latter. Since this current passes through one of the control windings of a magnetic amplifier 25 in the manner previously described, the electro-magnetic field, created by magnet 18 for bending the main beam, is altered to force it back toward the center line of crucible 10.

It will be evident that my invention affords simple yet effective means for preventing wandering of the area of impingence of an electron beam from the desired location, thereby improving the efficiency of vaporizing coating metal and protecting the crucible from excessive heating.

Although I have disclosed herein the preferred embodiment of my invention, I intend to cover as well any change or modification therein which may be made without departing from the spirit and scope of the invention.

I claim:

In the combination with an elongated crucible containing a charge of metal to be vaporized, of an electron-beam gun extending alongside said crucible adapted to deliver an arcuate beam of electrons onto the top of said charge and means maintaining the curvature of the paths of electrons making up said beam, the improvement comprising means responsive to a shift in the area of impingence of said beam on said charge and means controlled by said last-mentioned means for compensatorily adjusting said curvature-maintaining means, said shift-responsive means comprising means for maintaining a pair of electron beams extending along opposite sides of said crucible, in positions to be affected by the space charge of said first-mentioned beam on a lateral shift of said impingence area from its normal position.

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RICHARD M. WOOD, *Primary Examiner.*

JOSEPH V. TRUHE, Sr., *Examiner.*