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Schumacher

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[54] TEMPERATURE CONTROL FOR AN INDIRECTLY HEATED CATHODE FOR A HIGH POWER ELECTRON BEAM GUN

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[52] **U.S. Cl.** **315/107;** 315/117

[51] **Int. Cl.** **H05b 39/04**

[58] **Field of Search** 315/107, 117, 309

[56] **References Cited**

UNITED STATES PATENTS

2,530,169	11/1950	Lawrence et al.	315/107 X
2,677,787	5/1954	Litton	315/107 X
2,945,160	7/1960	Burk	315/107 X
2,954,470	9/1960	Brashear	315/107 X

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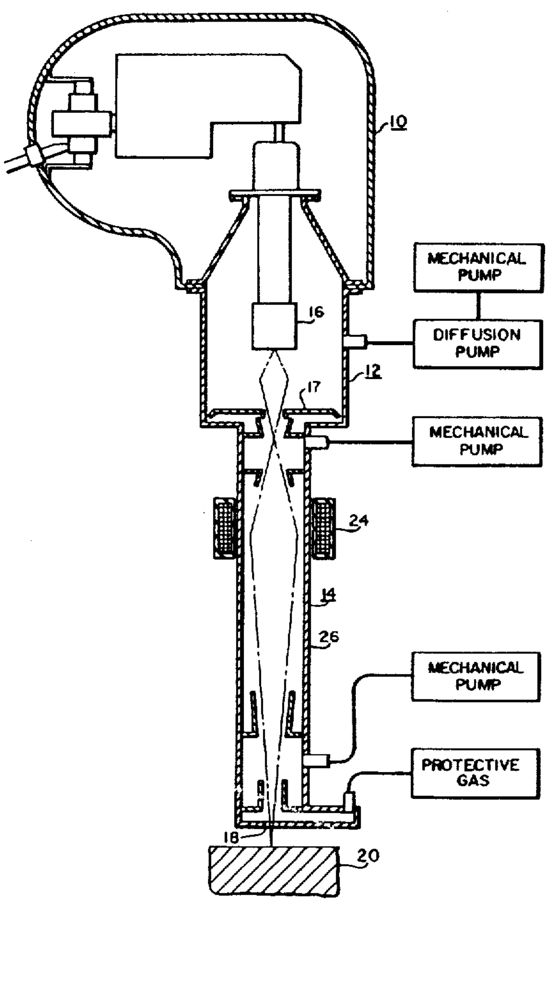
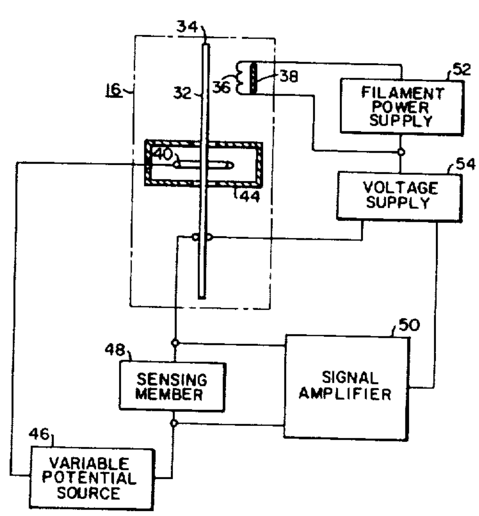
Attorney, Agent, or Firm—W. G. Sutcliff

[57] **ABSTRACT**

A method and apparatus for regulating and determining the temperature of a heated cathode in an electron beam system to regulate the magnitude of the beam current both during operation and prior to turn on. This is accomplished by measuring the thermionic emission of a well defined area of the cathode, regardless of whether the electron beam is being drawn from the cathode, and utilizing this measured signal to control the temperature of the heated cathode.

3 Claims, 4 Drawing Figures





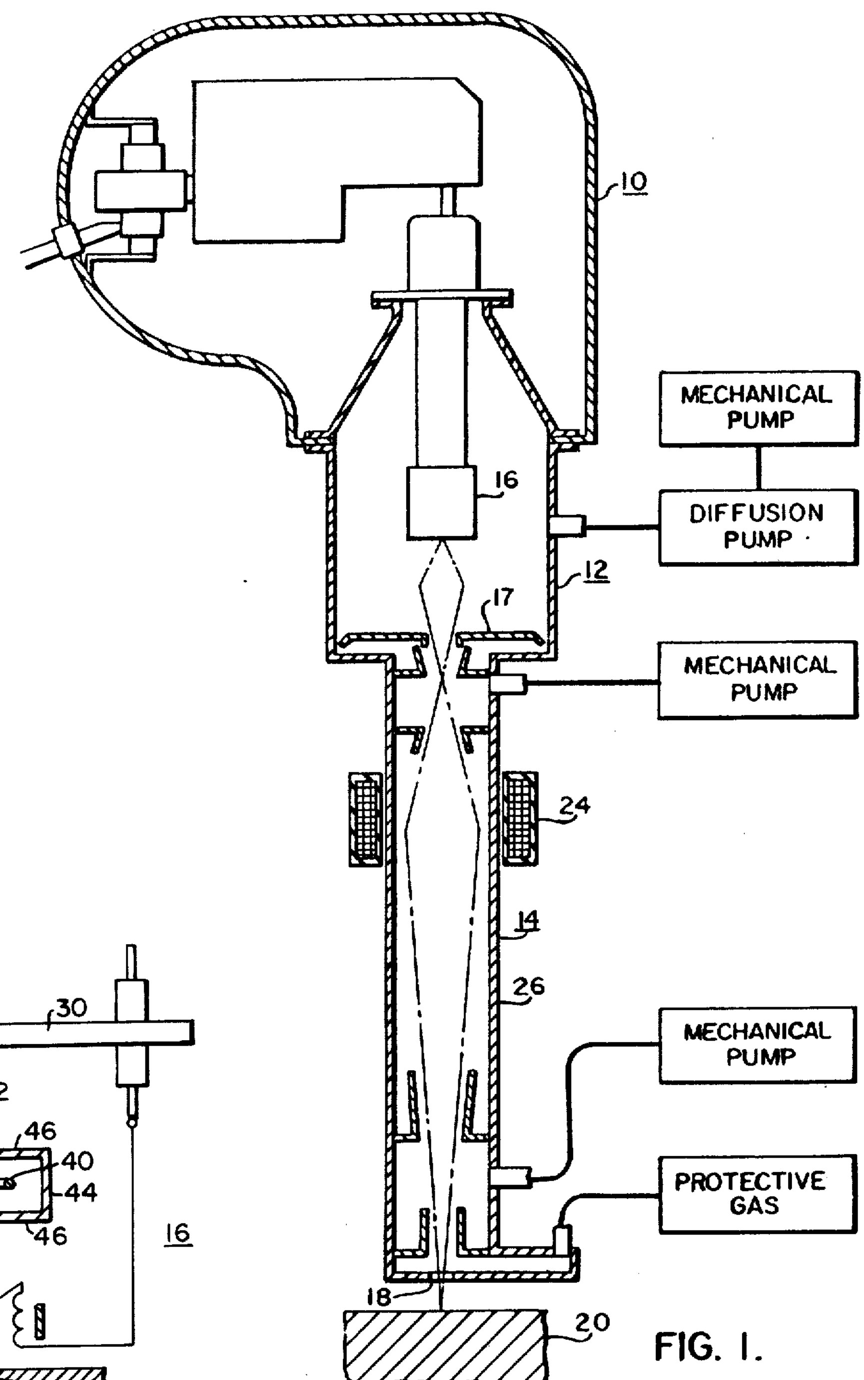

10
MECHANICAL PUMP
DIFFUSION PUMP
16
12
17
MECHANICAL PUMP
24
14
26
MECHANICAL PUMP
PROTECTIVE GAS
18
20

FIG. 1.

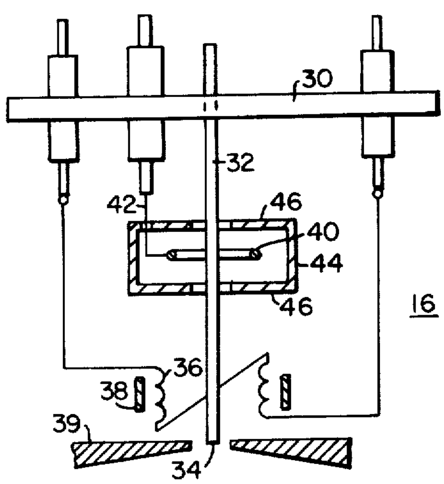

30
32
42
46
40
44
46
16
36
38
39
34

FIG. 2

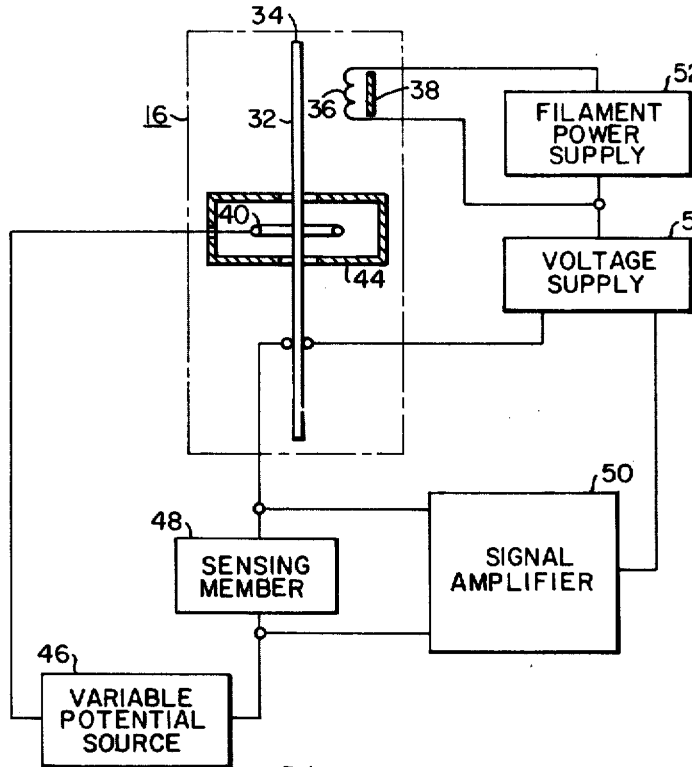

34
16
32
36
38
52
FILAMENT POWER SUPPLY
40
44
54
VOLTAGE SUPPLY
50
48
SENSING MEMBER
SIGNAL AMPLIFIER
46
VARIABLE POTENTIAL SOURCE

FIG.3

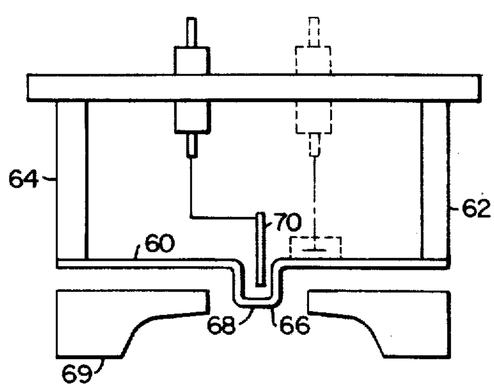

64
62
70
60
68
66
69

FIG.4

TEMPERATURE CONTROL FOR AN INDIRECTLY HEATED CATHODE FOR A HIGH POWER ELECTRON BEAM GUN

BACKGROUND OF THE INVENTION

In high power electron beam systems, such as an electron beam welder, it is often necessary to control the magnitude of the beam current very closely and also in some applications to predict the current that will appear at the first instance that the beam is gated on by application of a high accelerating voltage. The dominating parameter in most high energy electron beam systems which determines the current in the electron beam is the temperature of the cathode. It is found that determining the temperature from the emission current of such a cathode is a very accurate way to measure the current. It is know in the art to stabilize the current in the electron beam by means of a feedback loop that controls either the cathode heating power or a grid control. It is however important to be able to measure the cathode temperature prior to turning the electron beam on to insure that a proper amount of electron beam current is applied in a particular application. An excessive amount of current at the time of turn on of the electron beam can result for instance in creating a burn rather than a good weld.

SUMMARY OF THE INVENTION

In accordance with the present invention, an auxiliary electrode is associated with the cathode to derive electron emissions from the cathode from an area isolated from the electron beam source area to obtain a sensing signal representative of the temperature of the cathode. The signal thus derived by means of the auxiliary electrode may be utilized to control the heating power source connected to the cathode. In addition, the operating potential of the auxiliary electrode is such as to provide no substantial loading on the cathode, and the auxiliary electrode is shielded to provide a signal representative of a given area.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be had to the preferred embodiment, exemplary of the invention, shown in the accompanying drawings, in which:

FIG. 1 is a schematic showing of an electron beam welding apparatus incorporating the teachings of this invention;

FIG. 2 is an enlarged view of a portion of the electron gun illustrated in FIG. 1;

FIG. 3 is a schematic showing of a circuit that may be associated with the assembly shown in FIG. 2; and

FIG. 4 illustrates a possible modification of the cathode structure illustrated in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring in detail to FIG. 1, an electron beam apparatus for use in the atmosphere is illustrated. The apparatus basically consists of three sections **10, 12** and **14.** The top section or chamber **10** is a high pressure section which is filled with a suitable insulating gas, such as FS_6, and wherein the high voltage supplies are located. The middle section **12** contains the electron gun proper and is the section of the apparatus where the lowest vacuum is found. A cathode assembly **16** and anode **17** are mounted in the middle section **12.** The next chamber or lower chamber **14** is where the electron beam generated by the cathode assembly **16** is directed and passes through succeeding pumping stages and finally to a bottom orifice **18** where it goes on into the full atmosphere and bombards a workpiece **20.**

Several pumping stages and several pumping orifices are illustrated in FIG. **1.** The pressure increases stage by stage from the cathode assembly **16** on down to the workpiece **20.** The cathode environment is at a pressure of about 10^{-5} Torr. The succeeding stage is at a fraction of a Torr, and the final stage is about 200 Torr. A magnetic lens **24** may be utilized for focusing the electron beam.

The electron beam generated at the cathode assembly **16** is accelerated by an anode member **17.** The anode member **17** is at substantially ground potential. The cathode assembly **16** is at a negative potential of about 150,000 volts, while the succeeding stages of the system are all actually at ground potential. The electron beam proceeds through an aperture in the anode member **17** and is focused by the magnetic lens **24** and passes on through several orifices separating differential pressure areas which are maintained by the various pumps located progressively along the tubular housing **26.** The housing **26** may be of a suitable metal such as non-magnetic stainless steel.

FIG. **2** illustrates the cathode assembly **16.** The assembly **16** consists of a base member **30** from which extends a tungsten rod, bolt cathode **32.** The electron beam is drawn from the end face portion **34** of the bolt cathode **32.** An auxiliary cathode **36**, here a tungsten filament, surrounds the bolt cathode **32**, and generates electrons by which the bolt cathode is bombarded and heated. The auxiliary cathode **36** is maintained at a negative potential relative to bolt cathode **32.** A radiation shield **38** is provided about the auxiliary cathode **36.** A grid member or focusing electrode **39** may be provided surrounding the emission region **34.** Positioned between the secondary cathode **36** and the base **30** is an auxiliary electrode **40,** which typically serves as an anode, which may be a circular wire of a suitable material, such as tungsten, surrounding the bolt cathode **32.** An isolated lead-in member **42** is connected to the auxiliary anode **40** and passes through the base member **30.** a shield member **44,** effective against elective fields, for instance from the filament cathode **36,** is provided about the auxiliary anode **40** as illustrated, and consists of an annular member with an upper and lower inturned flange member **46.** The shield member **44** may be connected to the same potential as the bolt cathode **32.**

FIG. **3** illustrates a suitable circuit associated with the cathode assembly **16.** The auxiliary anode **40** is connected through a variable potential source **46** and a sensing member **48** to the cathode **32.** The sensing member **48** may be a current measuring device of the appropriate sensitivity and is scaled to indicate the cathode temperature as a function of the measured current. A signal amplifier **50** may be connected across the sensing element **48** to derive and amplify the signals generated therein. A filament power supply **52** is connected across the terminals of the secondary cathode **36** to provide the necessary excitation and heating of the secondary cathode to generate electrons for bombardment of the bolt cathode **32.** A voltage supply **54** is connected between the filament power supply and the bolt cathode 32 so as to provide a positive potential of about 100 to 600 volts between the secondary cathode 36 and the bolt cathode 32, so that the bolt cathode is at a more positive potential than the secondary cathode. A control signal derived from the signal amplifier 50 may be utilized to modify either the potential of the source 54 to thereby reduce the energy of the electrode bombarding the cathode, or may control the potential supply to the filament supply 52.

In the operation of the device, the temperature of the stem of the bolt member 32 is determined by measuring the thermionic emission from a well defined area of the stem. This area is of course beneath the auxiliary anode 40 and limited by shield 44. This thermionic emission will be obtained regardless of whether of not the main electron beam generated from the face 34 of the cathode is being drawn due to a high accelerating potential applied. The auxiliary electrode 40 may be placed at any convenient location opposite a section of the stem. The exact location is immaterial since a defined and ascertainable relationship exists between the temperature at the face 34 of the cathode and at any section along the stem. The auxiliary anode 40 may be of a suitable material such as tungsten. While the auxiliary anode 40 is shown here as a ring member, it can also be a pin-like member. The anode should be shielded, by shield member 44 of a suitable material such as tungsten or tantalum, against radiations and electrons that might arrive from the secondary cathode 36. A positive potential may be applied to the auxiliary electrode 40 with respect to the bolt cathode 32 such that all electrons are collected within the enclosed section of the bolt stem. This current is an indication of the bolt temperature.

Instead of placing a positive potential on the auxiliary electrode 40, it is also possible to utilize this electrode 40 at zero or a slightly negative potential. A negative potential of about −1 volt, or a variable potential from about −5 volts to 0 volts may be placed on the auxiliary electrode 40. A residual current will flow between bolt cathode 32 and electrode 40 which is also a measure of the temperature. This latter method has the advantage that no great amount of power is dissipated to the auxiliary electrode 40 from the cathode 32. The associated circuitry responsive to the temperature signal indication may regulate via the feedback loop either the filament supply or the accelerating voltage between the secondary cathode 36 and the bolt cathode 32.

In high power electron beam devices of the type described herein, the bolt cathode 36 typically is maintained at a high negative potential, from 1 W to several hundred kilovolts. The shield 44 is maintained at the same high negative potential as the cathode 36, while the auxiliary electrode 40 is maintained at for example about a 100 V more positive potential. The current flow from the cathode 36 to the auxiliary electrode 40 is typically of the order of a few milliamps to several hundred milliamps. The secondary current thus involves relatively low power as compared to the much higher power of the main electron beam, which will have a comparable current magnitude but over a much greater potential difference.

The circuit in which the secondary current flows will be at the same high negative potential relative to ground as the bolt cathode, and this complicates the current measurement and conversion to a readout which is a function of cathode temperature. In order to transmit this reading to ground the sensing member 48 can be a device in which the amplified current is passed through a filament, and the filament temperature and current flow therethrough are read with an optical pyrometer to avoid the high voltage problem. Suitable high voltage isolating step-down systems can also be used as part of the sensing member 48. Insofar as the signal amplifier 50 is also at a high negative potential it is also possible to avoid any connection between sensing member 48 and ground and simply to pass-on the signal from 48 to amplifier 50, but to adjust the reference value which is provided for amplifier 50 through an isolation link from ground, which can be an isolated potentiometer drive electrically connected to the amplifier 50.

While it is preferred for sensitivity purposes, that some potential difference be maintained between the cathode and the auxiliary electrode, it is within the scope of this invention to measure the thermionic emission from the heated cathode without need for maintaining a potential difference therebetween.

FIG. 4 illustrates a possible modification of the cathode assembly wherein a strap cathode member of a suitable material such as tungsten and indicated as item 60 is provided between two electrode supports 62 and 64. The strap 60 is provided with a form dimple 66 with the emission surface 68 thereon for generating the electron beam. A grid member 69 may be provided proximate the emission surface 68. A pin-type auxiliary electrode 70 may be positioned within this dimple as illustrated, or the auxiliary anode 70 may be disposed anywhere along the filament and a shielding member provided. In this cathode, of course, the cathode is heated directly by passing current through the cathode or filament strap 60.

Again, the current flow between the strap cathode 60 and more particularly, the dimple portion 66 and the auxiliary electrode 70 is sensed and used to develop a feedback signal for controlling the heating current through strap cathode 60.

The apparatus and method of the present invention thus permit an accurate temperature determination of the electron beam cathode prior to use of the main beam. This prevents for instance excessive initial currents which might burn through the work piece in a welding application, or low current flows which would mean a poor weld. Following initiation of the main electron beam, the cathode temperature could continue to be monitored and controlled utilizing the present invention or a conventional technique may be used which senses the main electron beam current.

I claim as my invention:

1. In combination with an electron gun for generating a high power electron beam, which electron gun includes an elongated cathode member and cathode heater means associated therewith for electron bombardment heating of the cathode member, with the electron beam being drawn from one end of said cathode member, and wherein the temperature of the cathode member significantly affects the electron beam emission, the improvement comprising a ring conductive electrode disposed about the cathode member at a location spaced from the electron beam emission end portion of the cathode member, with a secondary emitted electron current flow produced between said cathode member and said ring conductive electrode, a shielding enclosure disposed about the ring conductive electrode with the cathode member passing through

the shielding enclosure, and sensing means electrically connected to the ring conductive electrode for measuring the secondary emitted electron current and indicating the temperature of the cathode member as a function of said secondary emitted electron current.

2. The combination specified in claim 1, wherein the sensing means generates a signal which is a function of the cathode member temperature, and the sensing means is connected to the cathode heating means, whereby the generated signal is fed back to the cathode heating means to control the temperature of the cathode member.

3. The combination specified in claim 1 wherein the electron gun is disposed within a partially evacuated electron beam generating chamber of a high power electron beam system, and wherein said sensing means and control signal means associated with the electron gun are operative to sense said electron emission capability of the cathode of said gun with or without flow of the electron beam current.

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