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Thomas et al.

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[54] **ARRANGEMENT FOR REGULATING THE OPERATING PARAMETERS OF AN ELECTRON BEAM GENERATOR**

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[57] **ABSTRACT**

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315/101; 315/107; 315/299; 315/307

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[58] Field of Search 315/94, 98, 101, 107, 299,
315/300, 301, 307; 219/121 EB; 328/9, 270

[56] **References Cited****UNITED STATES PATENTS**

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5 Claims, 2 Drawing Figures

An arrangement for regulating the operating parameters of an electron beam generator in which the main cathode is indirectly heated by a directly-heated auxiliary cathode. A regulating circuit connected to the auxiliary cathode has three individual regulators connected in tandem for regulating the auxiliary cathode. Three separate signals corresponding to the accelerating voltage of the auxiliary cathode, the emission current of the auxiliary cathode, and the emission current of the main cathode are applied respectively to the inputs of the three individual regulators in feedback arrangement.

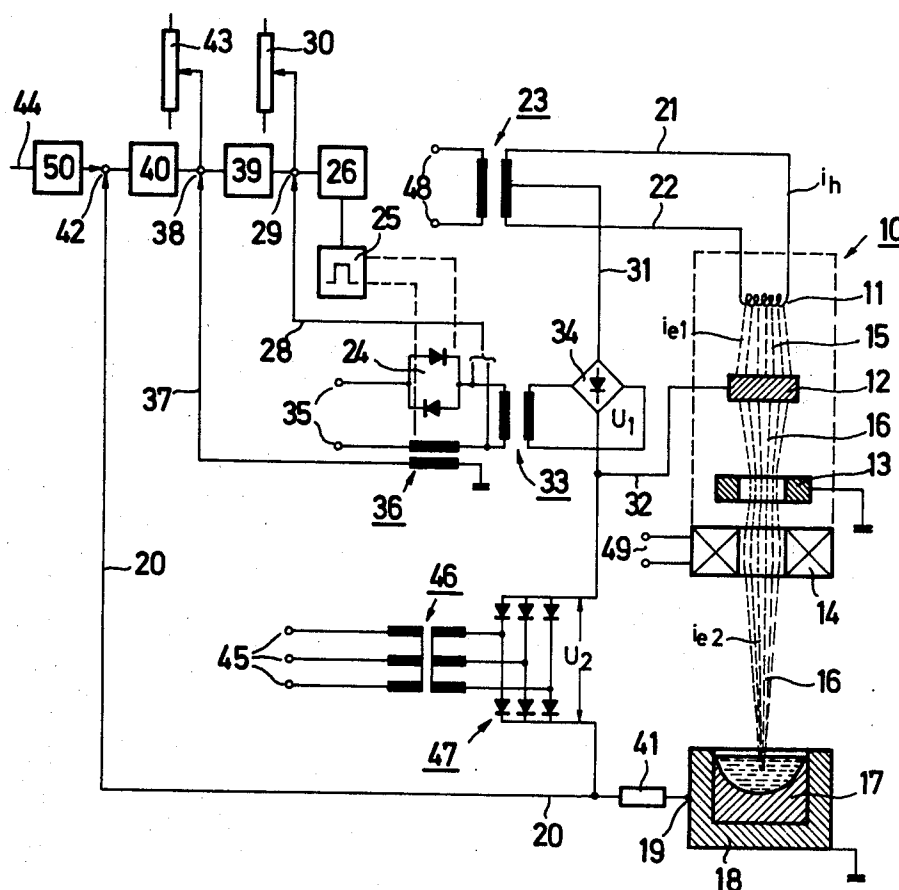


FIG. 1

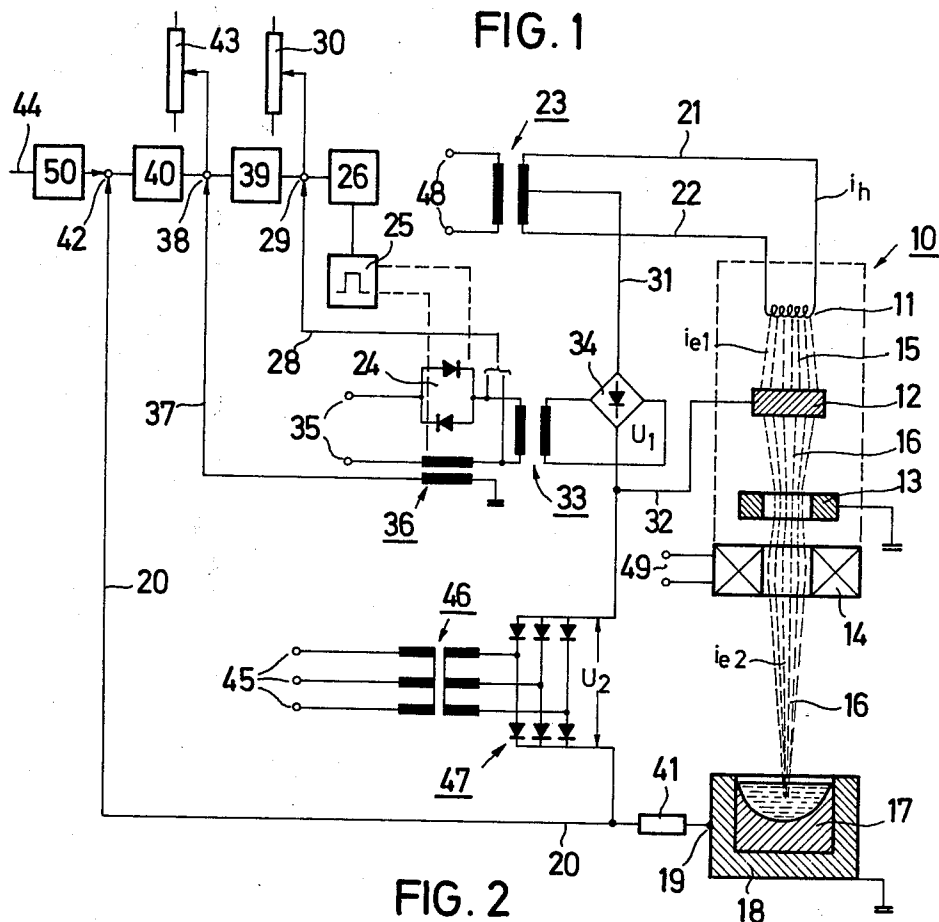
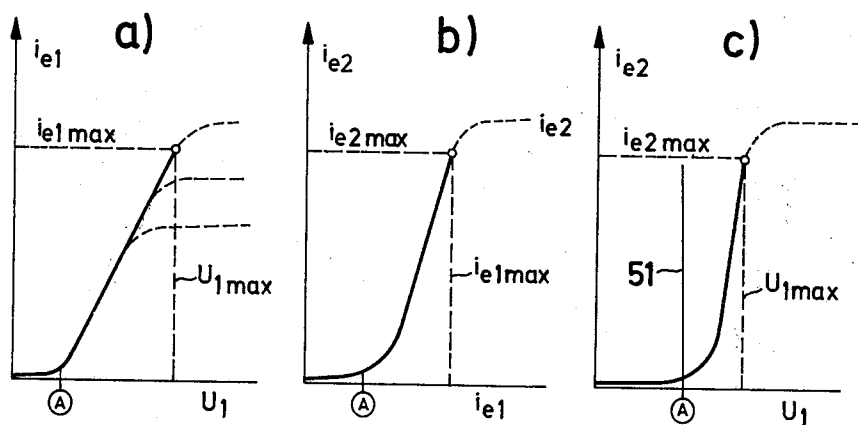


FIG. 2



ARRANGEMENT FOR REGULATING THE OPERATING PARAMETERS OF AN ELECTRON BEAM GENERATOR

BACKGROUND OF THE INVENTION

The present invention concerns an arrangement for the regulation of the operating parameters of an electron beam generator, particularly for purposes of evaporation, melting, welding, cutting and drilling. The arrangement provides for a directly-heated auxiliary cathode and a main cathode indirectly-heated by the auxiliary cathode. The invention includes means for feeding back into the regulating circuit a signal corresponding to the emission current of the main cathode, with a regulator for the energy supply connected ahead of the auxiliary cathode.

Indirectly-heated cathodes for electron beam systems become increasingly significant, since they are markedly superior to directly-heated cathodes with respect to power density and service life. Here, it is meaningful that the service life of a cathode is inversely proportional to the power density imposed on it. Indirectly-heated cathodes are also less sensitive to influences of the material to be treated or worked. Thus, there has been no lack of experiments to replace directly-heated electron beam systems with high-power guns by indirectly-heated ones. A considerable obstacle on this road, however, is the insufficient regulative behavior of the indirectly-heated guns.

An arrangement of the type described above belongs to the state of the art (DT-OS 1,935,710). In the arrangement described there, the fed-back signal, corresponding to the emission current of the main cathode, is applied to a parallel arrangement of regulating elements for both cathodes. However, here only one regulating circuit is operative at a time, so that the effect of an amplification of higher degree results. A stabilization of the known regulating system is practically impossible, so that a considerable tendency toward oscillation has to be accepted during regulating action. Here, it is particularly significant that electron beam guns for purposes of melting and treating materials are particularly subject to spontaneous changes in the operating parameters. In the known arrangement, the regulating circuit additionally influences the accelerating voltage at the main cathode. Thus, the electron velocities change, and necessarily also the focusing of the beams. But just the focusing of the beams should remain as constant as possible for certain material treating processes. Finally, the known system does not provide for the avoidance of dead time zones in the individual parts of the system.

Accordingly, it is an object of the present invention to avoid the disadvantages inherent in the known system, and to provide a circuit arrangement for an indirectly-heated cathode system having good stability behavior, short response time, small regulating errors, and easy operability, as against the state of the art.

SUMMARY OF THE INVENTION

The objects of the invention are achieved by providing that the regulating circuit for the auxiliary cathode consists of three individual regulators connected in tandem. Separate signals, corresponding to: (a) the accelerating voltage of the auxiliary cathode, (b) the emission current of the auxiliary cathode, and (c) the emission current of the main cathode, are applied to the

input of each regulator. The posed problem is fully solved by the arrangement according to the invention. The arrangement exhibits an excellent stability behavior with control action on the operating parameters. A step change in the preset value of a quantity results in an immediate adjustment free of overshoots. Because of an accelerating voltage that is kept constant, the focusing of the beams does not experience undesired changes. The dead time zones inherent in the system can be suppressed in each of the individual regulators, so that no addition of dead times results. Each of the individual disturbing quantities is fed back individually, so that each regulator can be stabilized by itself. Furthermore, each circuit can have a separate restriction of the current or voltage to preadjustable, individual values.

The suppression of the dead time zones is accomplished, again according to the invention, in that the inputs of the individual regulators each are equipped with a voltage supply, preferably adjustable, the polarity of which is opposite to that of the feedback signal. The voltage source can be constructed, for example, from an adjustable resistor, to which a potential is applied.

The novel features which are characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram, and shows the most essential parts of an electron beam gun, in accordance with the present invention; and

FIG. 2 are graphical diagrams of emission currents of the main and auxiliary cathodes as a function of the heating current or emission current of the auxiliary cathode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, in FIG. 1 is shown an indirectly-heated electron beam gun 10 of a type used for melting and evaporation purposes. The gun consists of a directly-heated auxiliary cathode 11, an indirectly-heated main cathode 12, an accelerating anode 13, and a focusing lens 14.

In operation, the auxiliary cathode 11 produces an emission current i_{et} , which brings the main cathode 12 to the desired operating temperature. Direction and power of the heating electron current 15 are determined by the accelerating voltage u_1 between the auxiliary and main cathodes. In turn, main cathode 12 emits an electron bundle 16 under the influence of its operating temperature and a potential difference u_2 with respect to the accelerating anode 13. The electron bundle is focused by electromagnetic focusing lens 14. The focusing action can be influenced by changing the focusing current applied at the terminals 49. Finally, the electron bundle 16 impinges on the material 17 to be treated, in the form of for example, a quantity of metal that is to be melted and/or evaporated by the beam energy converted into heat. The material 17 is in an electrically-conducting container 18, equipped with connection 19. Connection 19 is connected through

shunt 41 with the anode side of rectifier 47. Through conductor 20, the actual value of the emission current of the main cathode is fed to the regulating system. Details of the gun 10, its application, and the influence of its parameters are, however, well known in the art, so that they need not be discussed further.

Auxiliary cathode 11 is connected by the conductors 21 and 22 to transformer 23, which supplies heating current i_h and heating voltage for the auxiliary cathode 11. Heating current is supplied through terminals 48. The supply voltage can be stabilized. Through connection of the secondary side of transformer 23 over conductor 31 and the main cathode 12 by conductor 32 to rectifier 34 with transformer 33, a potential difference u_1 can be produced between auxiliary cathode 11 and main cathode 12, which serves as the accelerating voltage of the heating electron beam 15. Terminals 35 serve for connecting the system to a voltage supply. On the primary side of transformer 33 there is, for regulation of the acceleration voltage and hence the heating power, a thyristor control (SCR) 24, which receives the necessary gate trigger pulses from gate control circuit 25. The gate control circuit, in turn, receives the required regulating signals from an accelerating voltage regulator 26. A signal proportional to the accelerating voltage u_1 is fed back through conductor 28 to the mixing point 29 of the accelerating voltage regulator 26. This feedback accomplishes limiting the value of the accelerating voltage and therefore the temperature of the main cathode 12 to predetermined values. Furthermore, a compensating voltage supply is connected in opposition to the fed-back signal, which decreases the dead time zones of the gun caused by the system, and increases the speed of response. The required compensating voltage supply, in this case, contains an adjusting resistor 30.

The emission current i_{el} of auxiliary cathode 11 also is sensed on the primary side of transformer 33, and is fed back from there through transformer 36 and conductor 37 to the mixing point 38 of emission current regulator 39. This regulator is connected ahead of accelerating voltage regulator 26, i.e., the output signal of emission current regulator 39 is the desired input signal for the basic accelerating voltage regulator circuit. The feedback of the emission current i_{el} accomplishes the restriction of the emission current of the auxiliary cathode circuit and thus the temperature of main cathode 12 to predetermined values. Analogously to the arrangement at the input of accelerating voltage regulator 26, here, too, the mixing point 38 of the emission current regulator is connected to a compensating voltage supply with adjusting resistor 43. As a result, the dead time zone of the main cathode circuit can be eliminated. Each change of the emission current i_{el} is transmitted to the accelerating voltage regulator 26, and thus leads to the increase or decrease as required of the accelerating voltage of the auxiliary cathode.

The emission current regulator 40 for regulating the emission current of the main cathode 12 is connected ahead of emission current regulator 39 for auxiliary cathode 11. Thus, the output signal of emission current regulator 40 is the desired or input signal for the basic emission current regulator circuit of the auxiliary cathode. The mixing point 42 of regulator 40 receives, in addition to desired value signal 44, a signal corresponding to emission current i_{e2} of the main cathode 12 or the electron current of electron bundle 16. This signal is

generated by shunt 41, producing a voltage drop, and connected to connection 19 on container 18. The signal is transmitted over conductor 20. Each change in the desired values of the emission currents of the main and auxiliary cathodes is thus transmitted immediately to emission current regulator 39 and accelerating voltage regulator 26. In order not to exceed the dynamic capability of the cathode by sudden changes in the value of the desired signal 44, an element 50 can be connected ahead of the mixing point 42 to limit the slope of the rise of the desired signal.

The gun is supplied with high voltage through the connecting terminals 45, the three-phase transformer 46, and rectifiers 47. When several guns are supplied from a single voltage source, it is desirable that a transformer be connected on the high-voltage side of transformer 46 for obtaining the feedback signals.

FIG. 2 shows the functional relationship of the individual operating parameters of the gun circuit. FIG. 2a gives the dependence of the emission current i_{el} on the magnitude of the acceleration voltage u_1 . The emission current obeys the Schottky-Langmuir space charge equation, according to which $i_{el} = u_1^{3/2}$. Depending on the emission of the cathode, saturation (transition of the emission current curve to a horizontal direction) is reached for a greater or lesser voltage u_1 . FIG. 2b shows the dependence of the emission current i_{e2} of main cathode 12 on the emission current i_{el} of auxiliary cathode 11. FIG. 2c is substantially an overlay of FIGS. 2a and 2b, i.e., the dependence of the emission current i_{e2} of main cathode 12 on the accelerating voltage u_1 of the auxiliary cathode. It can be recognized that the individual elements of the gun system, seen from the viewpoint of regulating technology, suffer from dead time zones and proportional behavior. To eliminate the dead time zones, the signals applied respectively by adjusting resistors 30 and 43 to the mixing points 29 and 38, are used. These signals have the values designated by (A) in FIG. 2. The result is that 0-point of the coordinate system is shifted to the point (A), illustrated in FIG. 2c by the second ordinate 51.

Without further analysis, the foregoing will so fully reveal the gist of the present invention, that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. An arrangement for regulating the operating parameters of an electron beam generator comprising, in combination, an electron emissive main cathode with emission current; an electron emissive auxiliary cathode with emission current for heating indirectly said main cathode, means for heating directly said auxiliary cathode; means for generating an accelerating voltage between said main cathode and said auxiliary cathode, voltage regulating means connected to said auxiliary cathode and having three single regulators connected in tandem for regulating the accelerating voltage between said auxiliary cathode and said main cathode; feedback means for feeding back to said regulating means a signal corresponding to the emission current of said main cathode, said three single regulators having applied to their respective inputs, one of three separate signals corresponding to the accelerating voltage

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of said auxiliary cathode, the emission current of said auxiliary cathode, and the emission current of said main cathode.

2. The arrangement as defined in claim 1 including input means for applying a desired input signal to said regulating means; a mixing junction between said input means and said regulating means for receiving said signal corresponding to the emission current of said main cathode; and limiting means connected ahead of said mixing junction to limit the slope of the rise of said desired input signal.

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3. The arrangement as defined in claim 1 wherein said regulating means is a source of energy supply.

4. The arrangement as defined in claim 1 including a source of compensating voltage connected to each input of said three single regulators and having a polarity opposite to the polarity of the respective feedback signal applied to the input of the respective single regulator.

5. The arrangement as defined in claim 4 including adjusting means for varying said compensating voltage.

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