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

[75] Inventors: **Friedrich Werner Thomas**, Niedermittlau; **Gerhard Vock**, Hanau am Main, both of Germany

[73] Assignee: **Leybold-Heraeus-Verwaltung G.m.b.H.**, Cologne, Germany

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[52] **U.S. Cl.** ..... **315/106;** 219/121 EB; 315/98; 315/101; 315/107; 315/299; 315/307

[51] **Int. Cl.** **H05b 7/02;** B23k 15/00

[58] **Field of Search** ..... 315/94, 98, 101, 107, 299, 315/300, 301, 307, 106; 219/121 EB; 328/9, 270

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Primary Examiner—James W. Lawrence
Assistant Examiner—E. R. LaRoche
Attorney, Agent, or Firm—Joseph F. Padlon

[57] **ABSTRACT**

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 heating current 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.

5 Claims, 2 Drawing Figures

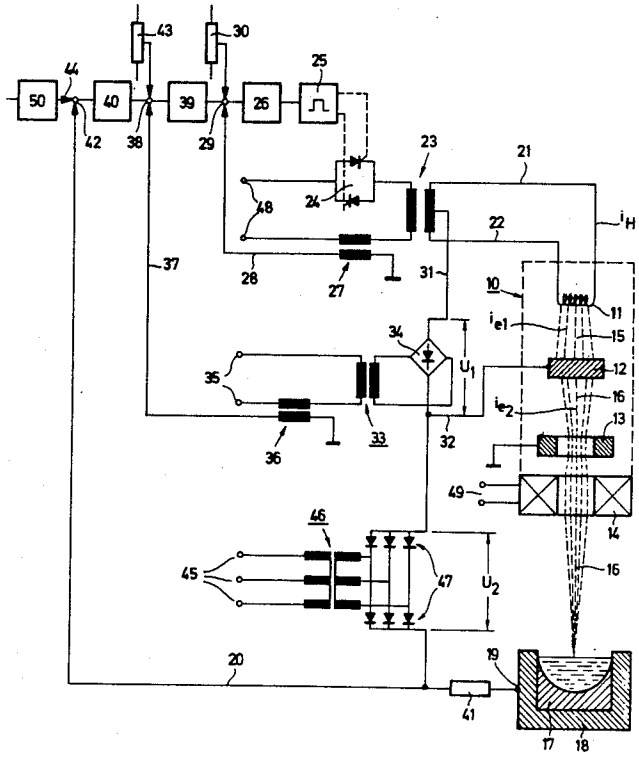


FIG. 1

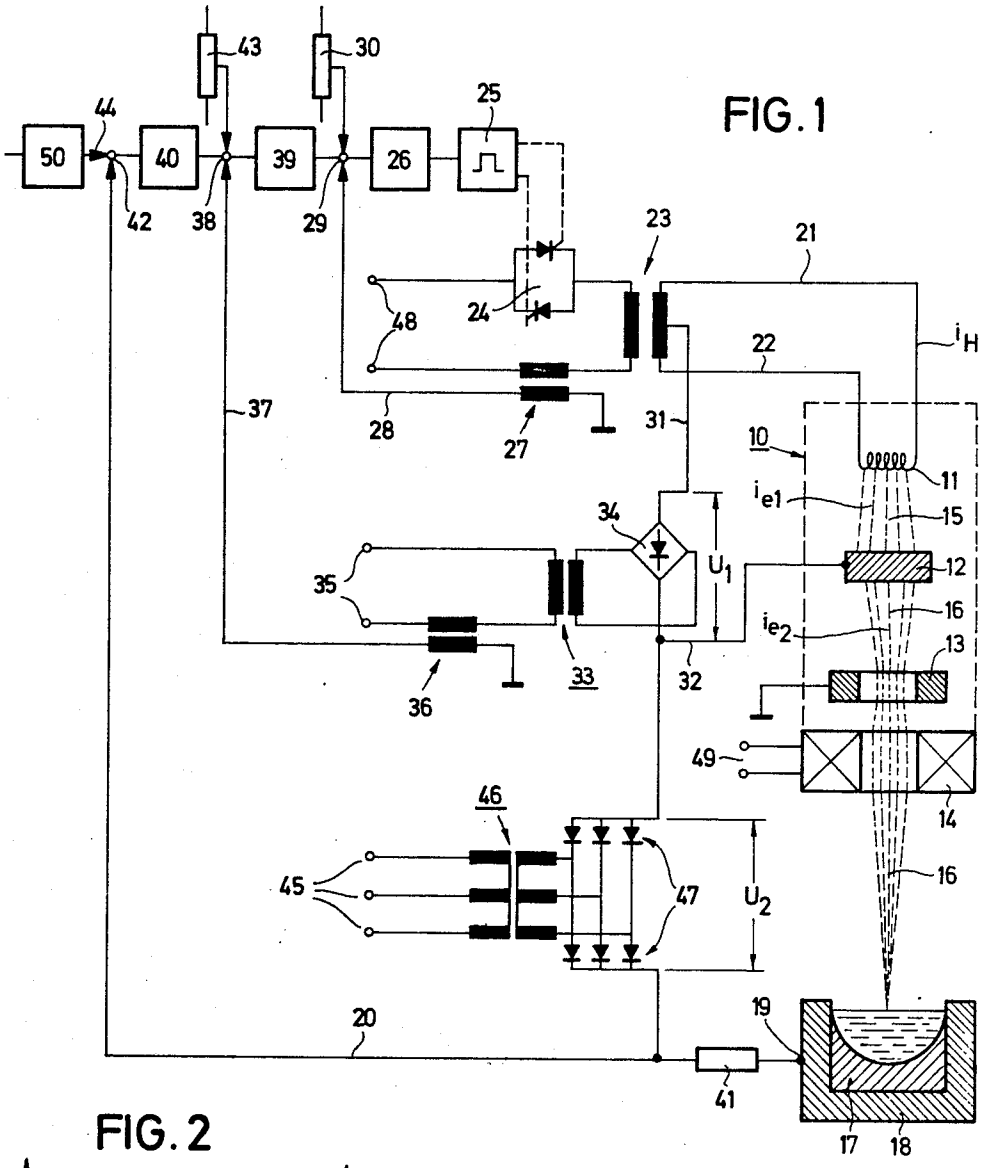
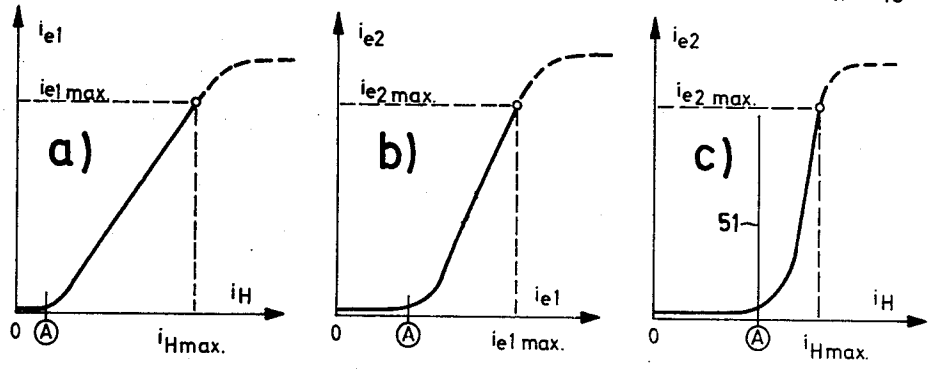

50
40
39
26
25
44
42
38
29
43
30
23
21
24
48
22
i_H
37
28
27
31
10
11
i_{e1}
15
34
U_1
12
35
16
i_{e2}
13
36
33
32
49
14
46
45
47
U_2
16
20
19
41
17
18

FIG. 2


i_{e1}
$i_{e1\,max.}$
a)
i_H
0
A
$i_{Hmax.}$
i_{e2}
$i_{e2\,max.}$
b)
i_{e1}
0
A
$i_{e1\,max.}$
i_{e2}
$i_{e2\,max.}$
c)
51
i_H
0
A
$i_{Hmax.}$

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 generator has 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 to be noted 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 path, however, is the insufficient regulative behavior of the indirectly-heated guns.

An arrangement of the type described above is known in the art (DT-OS 1,935,710). In this known arrangement described there, the feed-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 a 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 material 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 rays. But just the focusing of the rays 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 which has good stability behavior, short response times, small regulating errors, and easy operability, as against the conventional arrangements.

SUMMARY OF THE INVENTION

The objects of the present 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 heating current 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 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 over-shoots. 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 to an individual, preadjustable value.

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 an adjustable supply. The polarity of the voltage is opposite that of the fed-back signal. The voltage source can be constructed, for example, from an adjustable resistor, to which a potential is applied.

The novel features which are considered as 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 shows graphical diagrams of emission currents of the main and auxiliary cathodes as a function of the emission current or heating current of the auxiliary cathode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, an indirectly-heated electron beam gun **10** is 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_{el}, which brings the main cathode 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 the 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 a connection **19** for a conductor **20** leading to a regu-

lating circuit. Details of the gun **10**, its application, and the influence of its parameters are, however, known in the art, so that they need not be discussed further here.

Auxiliary cathode **11** is connected by the conductors **21** and **22**, to transformer **23**, which supplies heating current i_h and heating voltage for auxiliary cathode **11**. On the primary side of transformer **23** there is a thyristor control (SCR) **24** for regulating the heating power, which receives the necessary gate trigger pulses from gate control circuit **25**. The gate control circuit, in turn, receives the required regulating signals from heating current regulator **26**. Heating current is supplied through connecting terminals **48**. A signal proportional to heating current i_h is fed through transformer **27** and conductor **28** to the mixing point **29** of the heating current regulator **26**. This feedback accomplishes restriction of the value of the heating current and therefore the temperature of auxiliary cathode **11** to predetermined values. Furthermore, a compensating voltage supply is connected in opposition to the feedback signal, which decreases the dead time zone of the gun caused by the system and increases the speeds of response. The required compensating voltage supply, in this case, contains an adjusting resistor **30**.

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**. This serves as the accelerating voltage of the heating electron stream **15**. Terminals **35** serve for connecting the system to a voltage supply.

The emission current i_{el} of the auxiliary cathode **11** is also sensed on the primary side of transformer **33**, and is fed back from there via transformer **36** and conductor **37**, to the mixing point **38** of the emission current regulator **39**. Regulator **39** is connected ahead of heating current regulator **26**, i.e., the output signal of the emission current regulator **39** is the desired signal or input signal for the basic heating current regulator circuit. The feedback of the emission current i_{el} accomplishes that the value of the emission current of the auxiliary cathode circuit and thus the temperature of main cathode **12** can be restricted to predetermined values. Analogously to the arrangement at the input to heating current regulator **26**, here, too, there is a compensating voltage supply with adjusting resistor **43**, applied to the mixing point **38** of the emission current regulator **39**. This eliminates the dead time zone in the operation of the circuit of the main cathode. Each change of the emission current i_{el} thus is immediately transmitted to the heating current regulator **26**, and therefore always leads to the required increase or decrease of the heating current of the auxiliary cathode.

An emission current regulator for regulating the electron current of the main cathode **12** is connected ahead of the emission current regulator **39** for the auxiliary cathode **11**. Thus, the output signal of the emission current regulator **40** is the desired signal or input signal for the basic emission current regulator circuit of the auxiliary cathode. The desired signal **44** and a regulating signal corresponding to the emission current i_{e2} of main cathode **12** or the electron current of the electron bundle **16** are applied to mixing point **42** of the regulator **40**. The regulating voltage drop required for the signal is generated by shunt **41**, connected to terminal **19** of container **18**, and is fed through conductor **20**. Each change in the desired values of the emission currents of the main and auxiliary cathodes is thus transmitted immediately to the emission current regulator **39** and the heating current 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 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, a transformer is advantageously connected on the high-voltage side of transformer **46** for obtaining the feedback signals.

FIG. **2** shows the functional relationships of the individual operating parameters of the gun circuit. FIG. **2***a* gives the dependence of the emission current i_{el} of the auxiliary cathode **11** on the value of the heating current i_h. FIG. **2***b* gives the dependence of the emission current i_{e2} of the main cathode **12** on the emission current i_{el} of the auxiliary cathode **11**. FIG. **2***c* is substantially an overlay of FIGS. **2***a* and **2***b*, i.e., the dependence of emission current i_{e2} of the main cathode **12** on the heating current i_h 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 from 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 (A) in FIG. **2**. The result is that the O-point of the coordinate system is shifted to the point (A), illustrated in FIG. **2***c* 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 apsects 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 heating current and 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, regulating means connected to said auxiliary cathode and having three single regulators connected in tandem for regulating the heating current of said auxiliary cathode; feedback means for feeding back to said regulating means a signal corresponding to the emission current of said main cathode, said three signal regulators having applied to their respective inputs, one of three separate signals corresponding to the heating current 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.

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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