219-121 OR

09-12-72 OR 3,691,341

United States Patent

Roiron et al.

[15] **3,691,341**

[45] **Sept. 12, 1972**

[54] **IMPROVEMENTS TO THE CONTROLLING OF FOCUSSING OF ELECTRONIC BOMBARDMENT**

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[22] Filed: **Aug. 13, 1969**

[21] Appl. No.: **849,848**

[30] **Foreign Application Priority Data**

Aug. 14, 1968 France..........................163168

[52] **U.S. Cl.**.....................**219/121 EM,** 250/49.5 AE

[51] **Int. Cl.**...**B23k 15/00**

[58] **Field of Search**....219/117, 121, 121 EB, 121 L; 250/49.5, 41.8

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[57] **ABSTRACT**

Optimum focusing of an electron beam on a metal part more particularly in electron beam welding is obtained by intercepting the ionic and/or electronic currents radiating from the metal part under the influence of the impact of the beam, and controlling the focusing of the electron beam as a function of the currents to bring the currents at a minimum.

To this end, an electrically conducting ring is arranged coaxially with the electron beam which is focused by means of e.g., an electromagnetic coil. The ring is arranged between the metal part and the focusing coil, and is part of a biasing circuit adapted to impart a given polarity to the ring. Current passing through the ring is measured and a servo-control controls the focusing to reduce the current to a minimum. At least one diaphragm or mask is arranged around the electron beam between the focusing coil and the ring, and a grid having a polarity opposed to that of the ring is arranged between the metal part and the ring.

6 Claims, 13 Drawing Figures

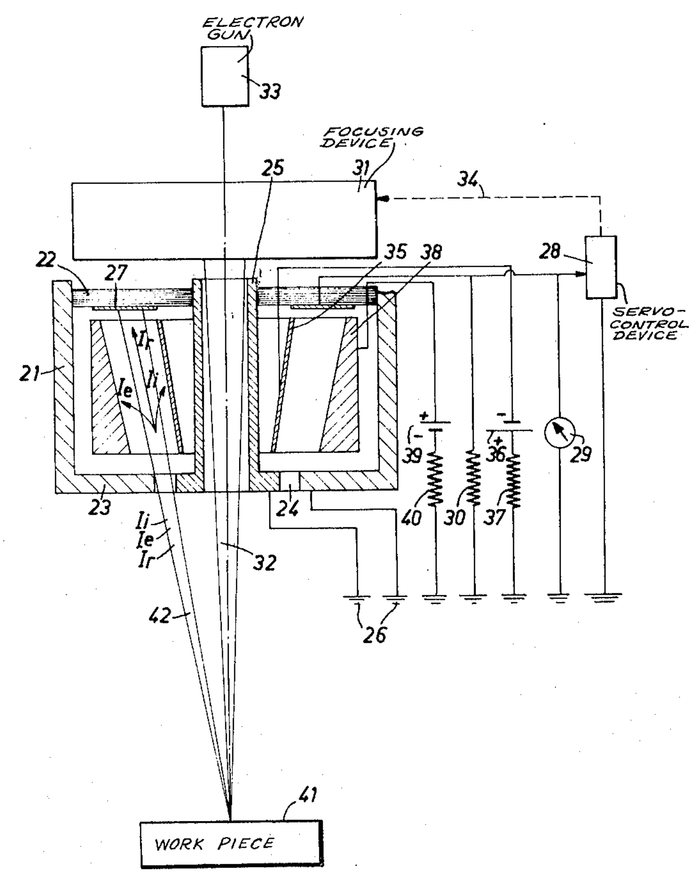

FIG.1

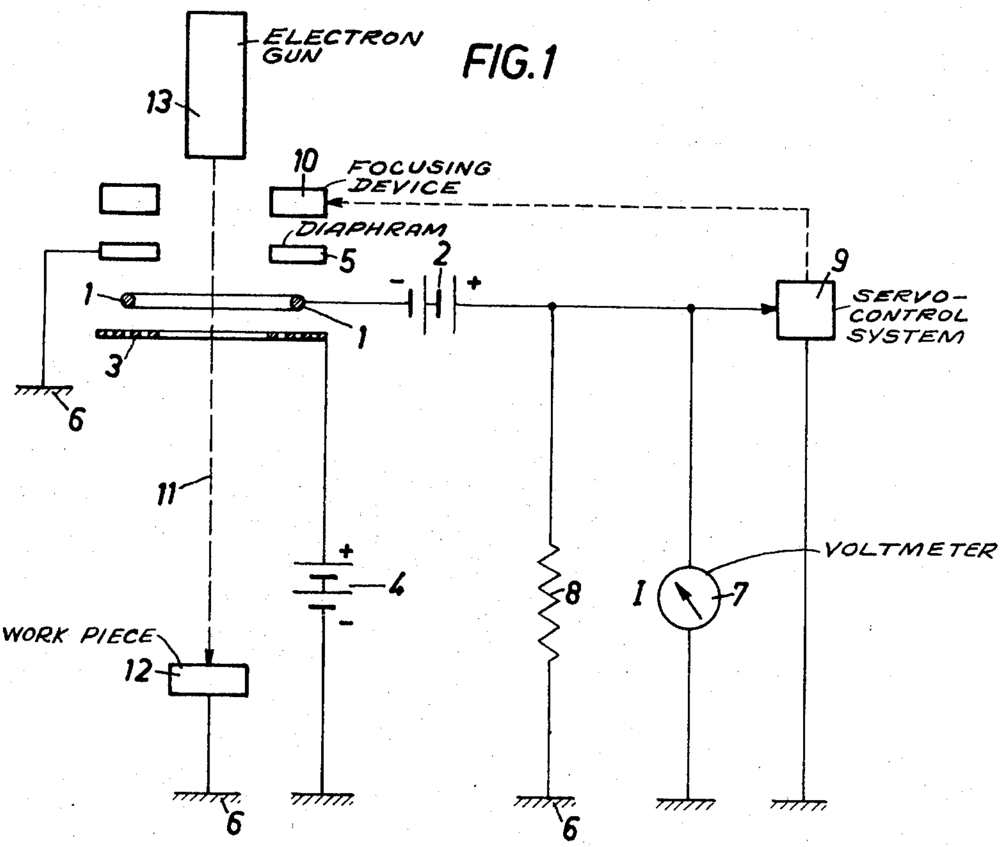

FIG. 2

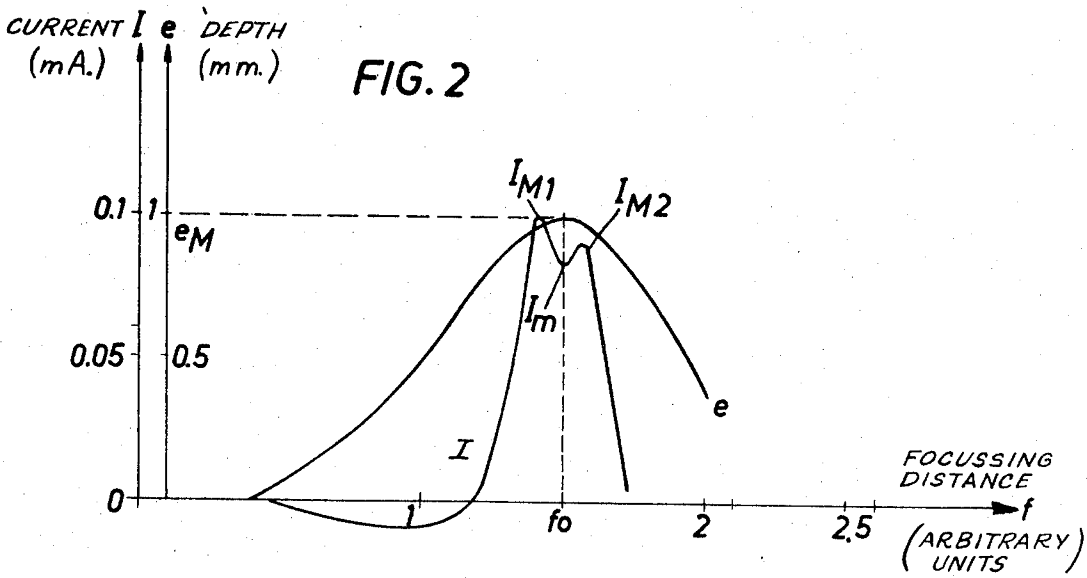

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FIG.3

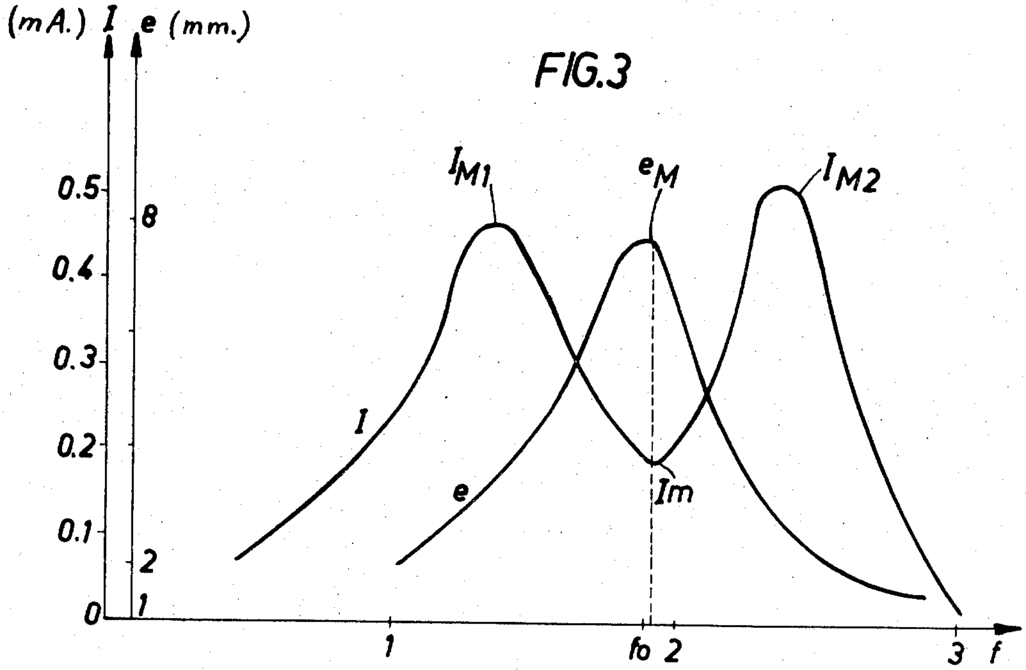

FIG.4

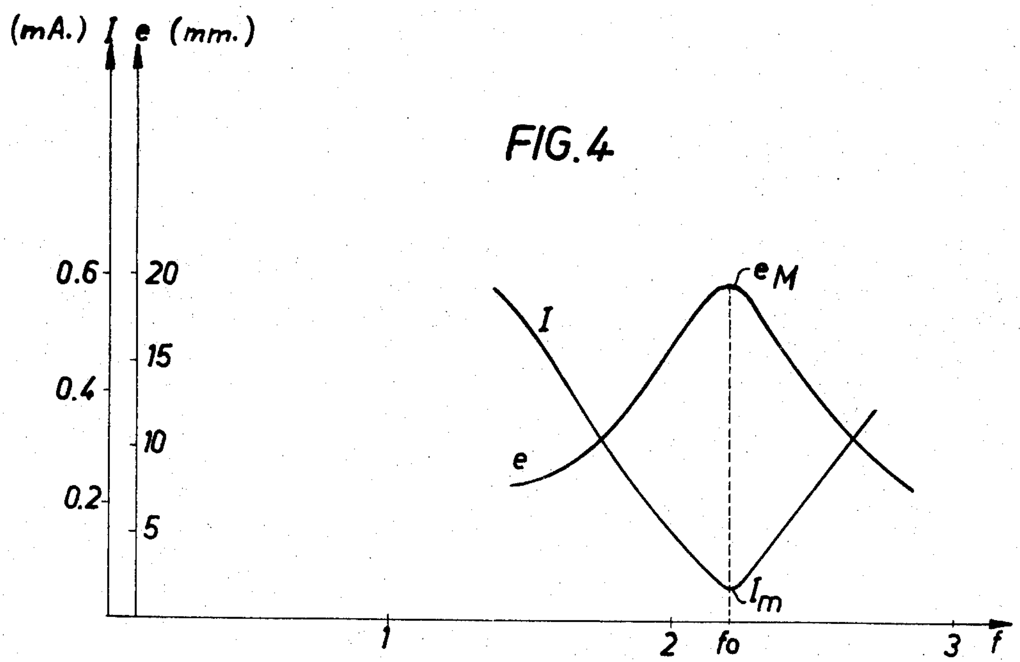

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FIG. 5

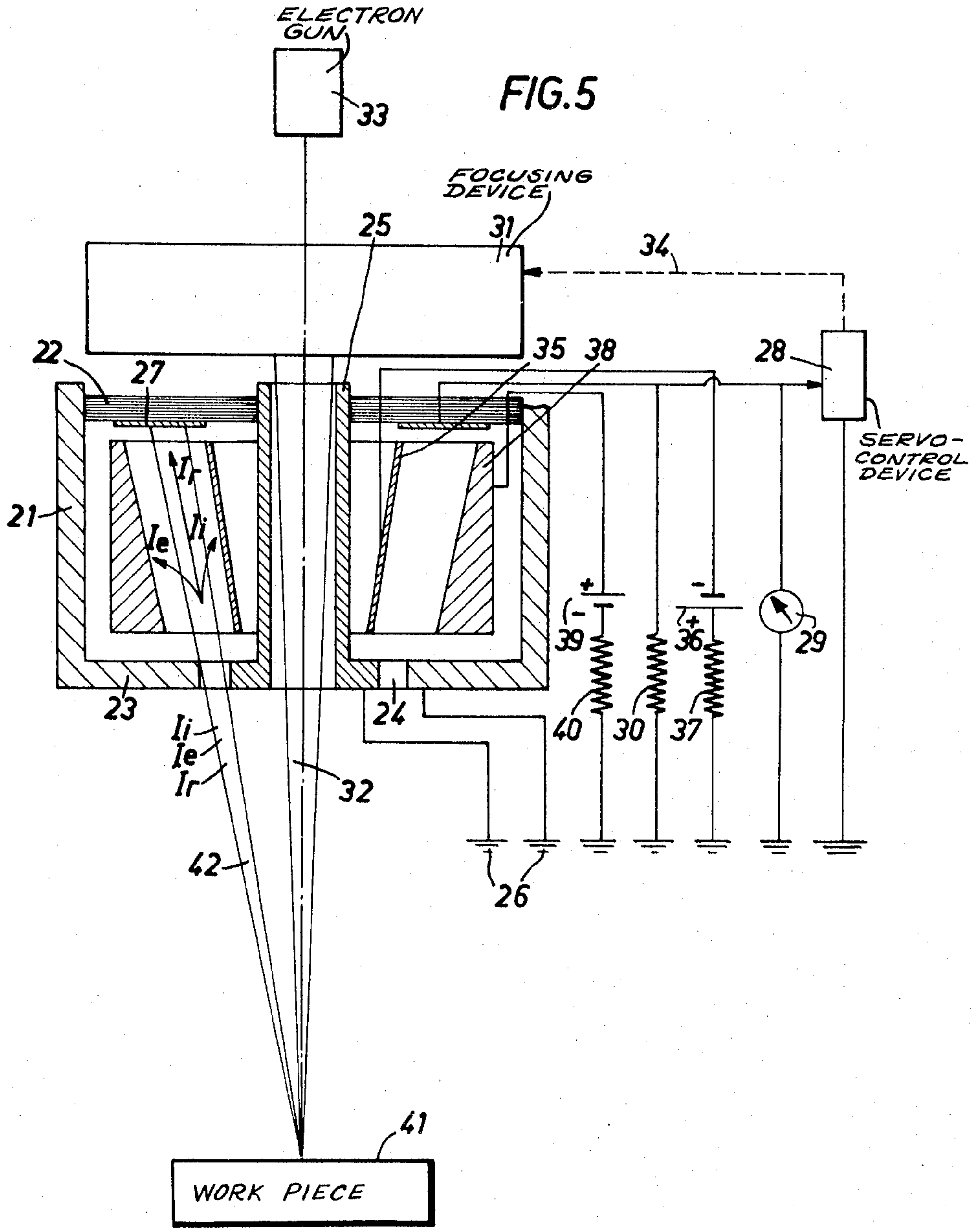

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FIG.6a

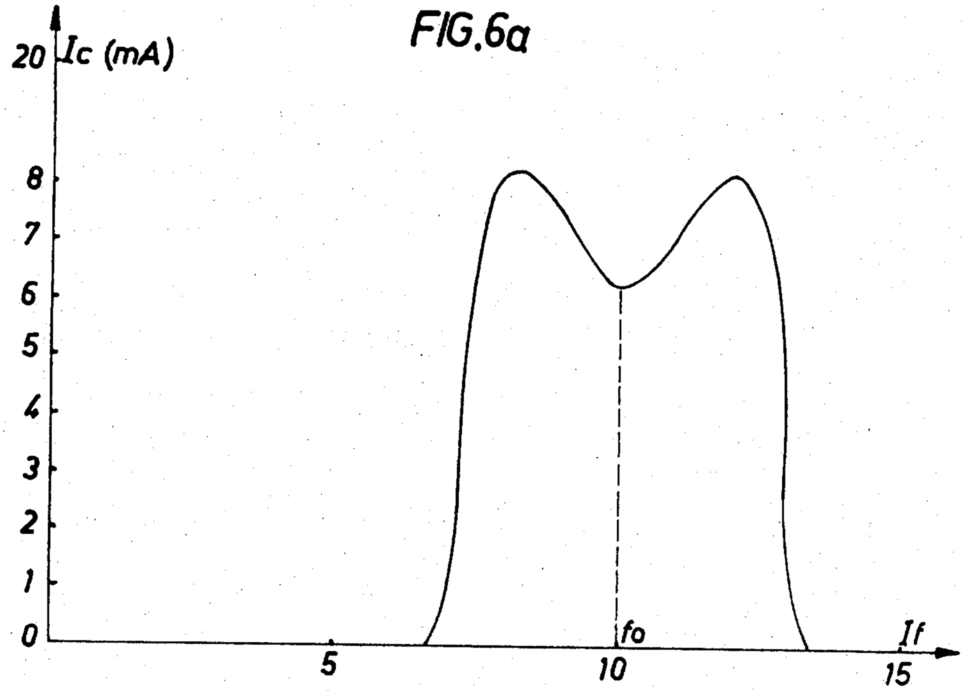


FIG.6b

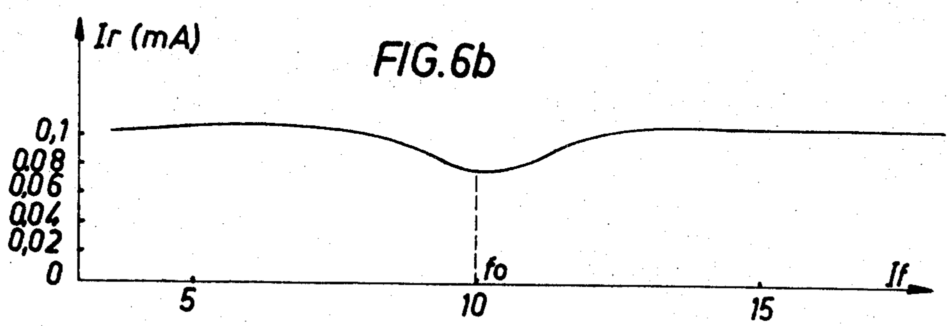
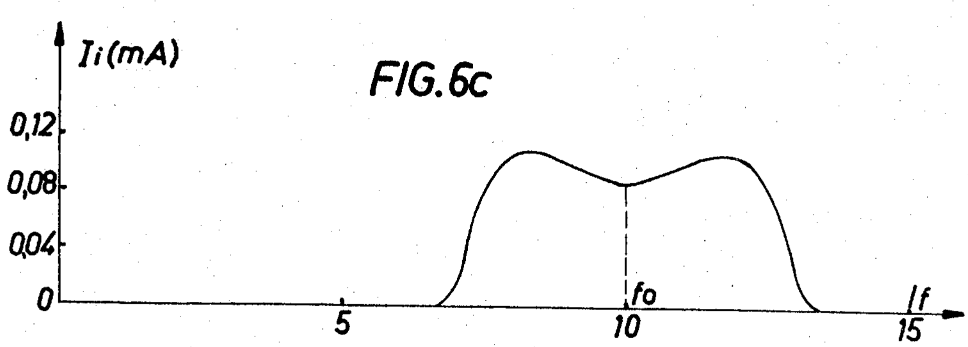


FIG.6c



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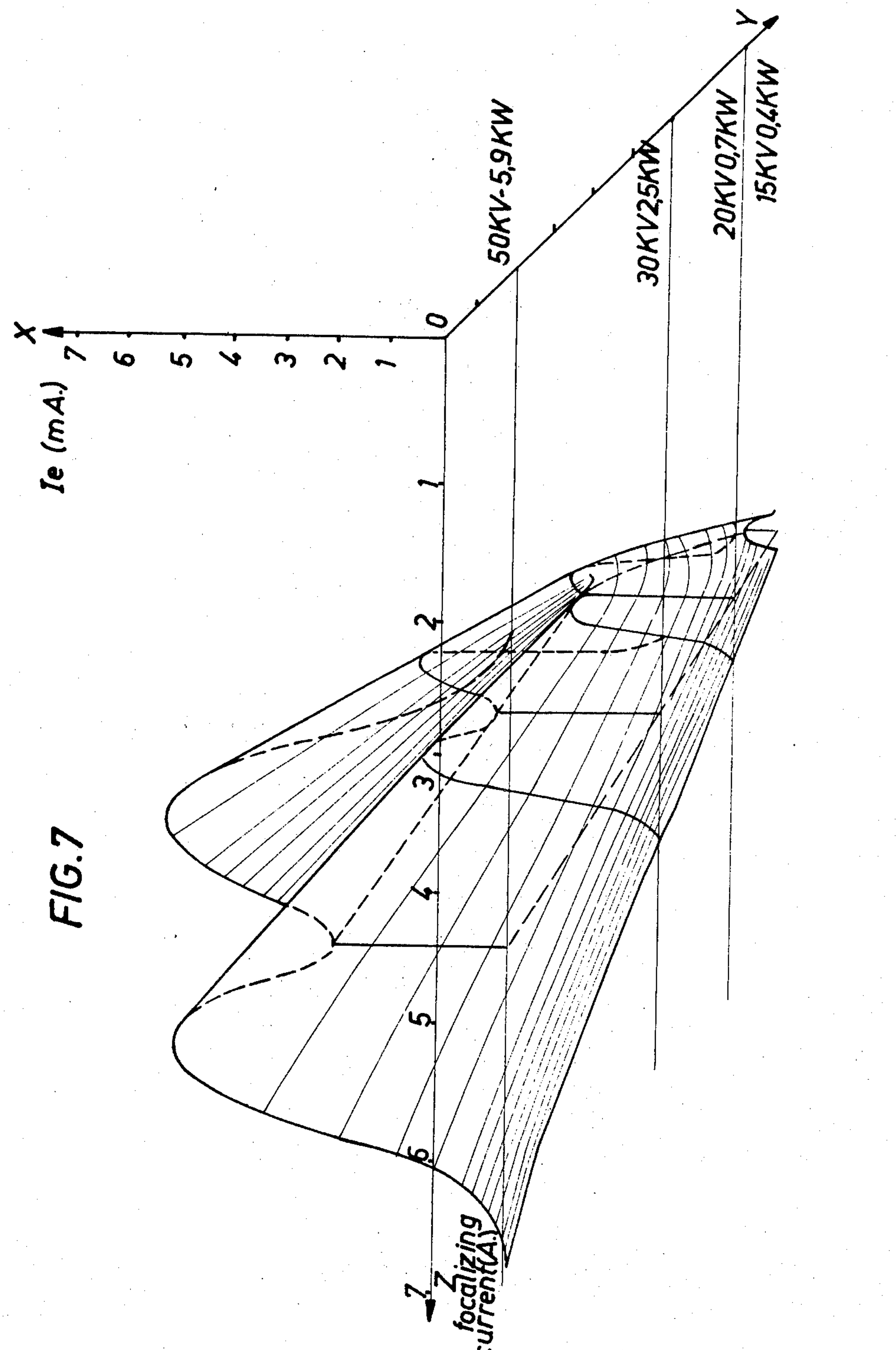

FIG.7

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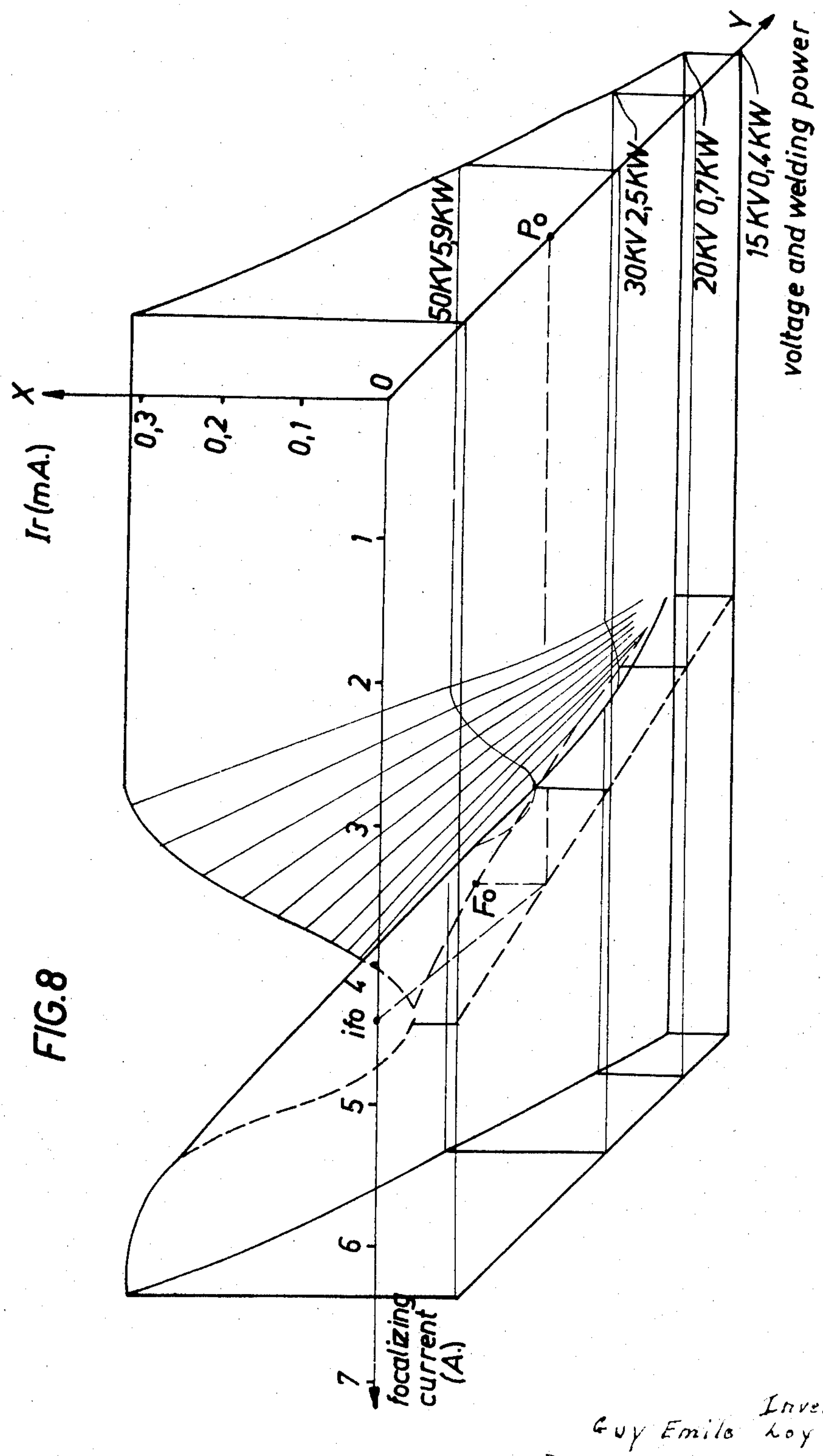

FIG.8

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FIG. 9

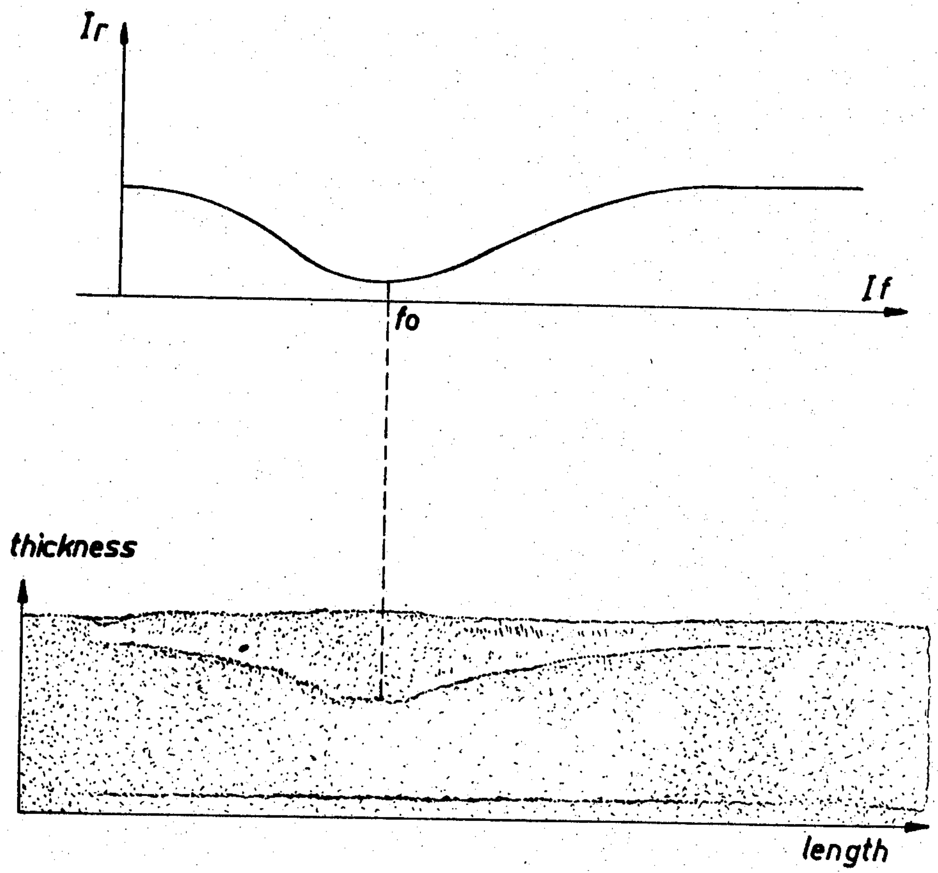

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FIG.10

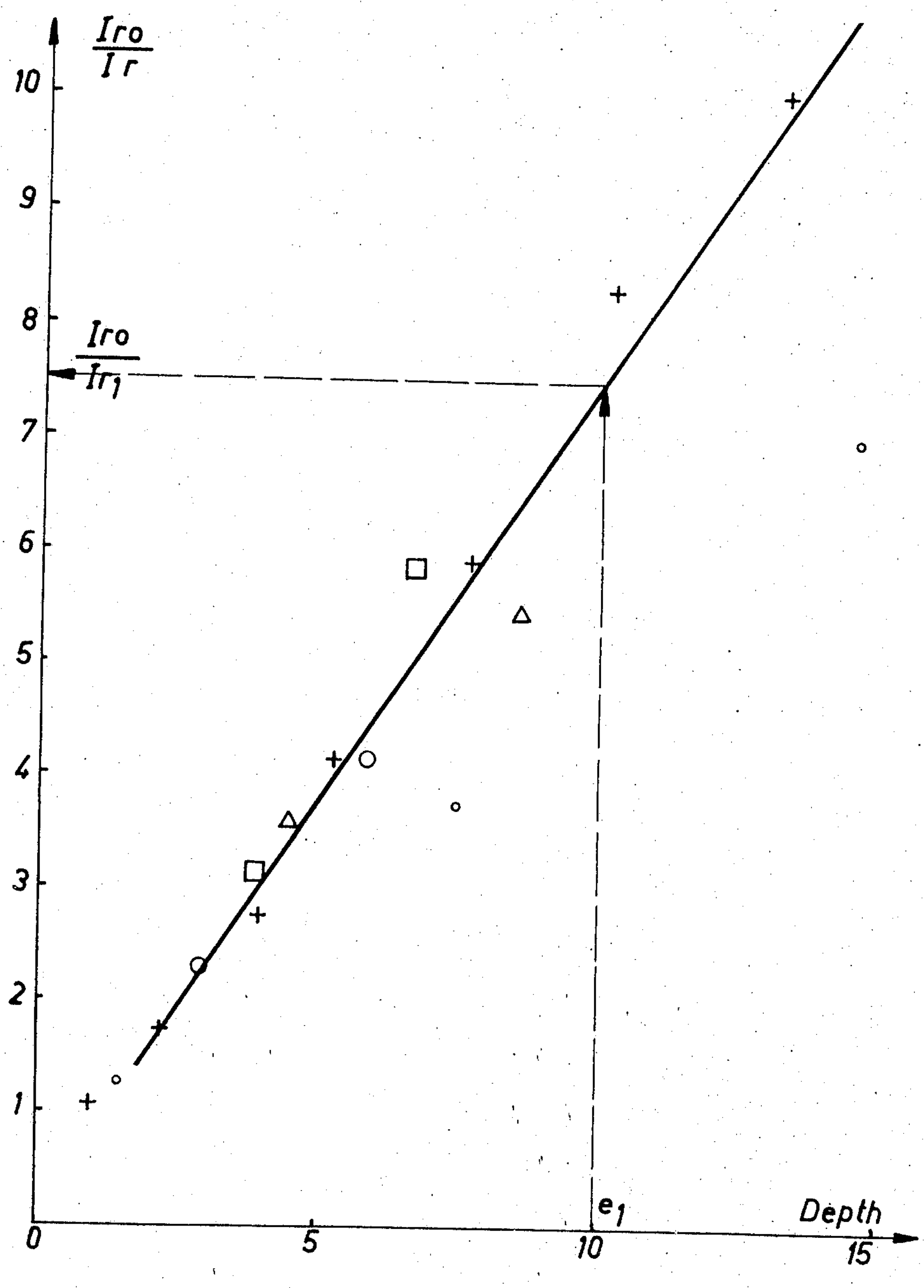

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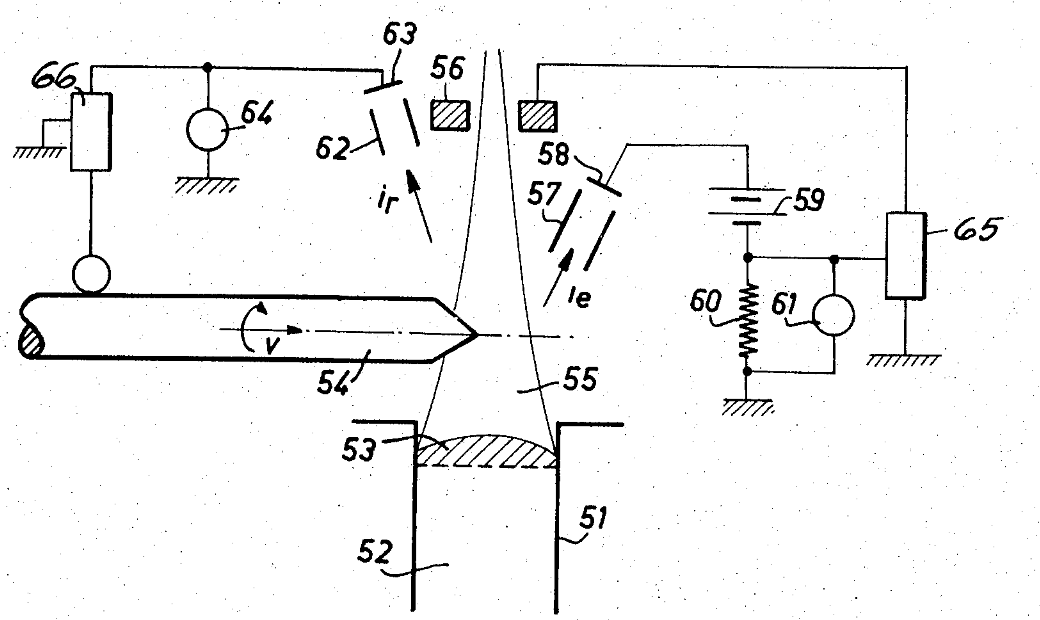
FIG.11



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IMPROVEMENTS TO THE CONTROLLING OF FOCUSSING OF ELECTRONIC BOMBARDMENT

This invention relates to a method and a device for controlling the focussing of an electronic bombardment beam, e.g., for piercing, cutting, welding or melting metal parts.

In devices which operate by means of such an electron beam, for instance in welding devices, the control of the electron beam is operated either by hand, or by the action of the useful parts of the beam which returns to the feed, by means of a measuring apparatus and under the form of an electric current.

The methods and devices of the prior art have a certain number of inconveniences.

First, the known technique used for the optimum focussing control is empirical in the case of hand control, and approximative in the case where said control is obtained through measuring the current which passes through the parts on which the beam operates.

The second inconvenience results from the fact that the previously known devices do not procure the possibility of taking the quality of the welding seam during the welding operation, the only possibility for such a control being after the welding is completed, on metallographic sections.

A further inconvenience of the known methods and devices is the difficulty to weld or otherwise treat metal parts having the shapes which require a variation in the shooting range of the electron gun during the welding or other operation which is performed.

The main object of the present invention is to remedy the inconveniences of the known methods and devices to welding by electronic bombardment.

A further object of the invention is to provide a method for the optimum focussing of an electron bema.

Still further object of the invention is to provide a device for such an optimum focussing of an electron beam on a metal part.

Generally speaking, the method according to the invention for controlling the focussing of an electron beam issued from an electron gun and impacting on a metal part, particularly for a welding operation, consists in intercepting the ionic and/or electronic currents radiating from said metal parts under the influence of the impact of said electronic beam, measuring the value of said currents and servo-controlling the focussing of said electron beam as a function of said value of the current of high energy to bring said value to a minimum.

The servo-control according to the invention constitutes a means for automatically varying the focussing distance until the optimum focussing is obtained.

The invention is based on results which have been obtained in the course of a systematic study of the secondary emissions radiated by the material which constitutes the work-piece under the influence of an electron beam the focussing of which holding constant is varied while other values such as the beam carrying capacity, the speed of travel of the beam with respect to the work-piece and the shooting range.

Said study has led particularly remarkable results. It has been found that when the work-piece was submitted to an electron beam the focussing of which was substantially shorter than the optimum focussing distance, the work-piece re-emitted a radiation of "retro diffused" electrons, that when the work-piece submitted to an electron beam the focussing of which is substantially near the optimum focussing, said work-piece emitted a mixed radiation of electrons and ions, that when the work-piece is submitted to an electron beam the focussing of which is substantially the optimum focussing, the current collected by the correcting device, which current is formed of ions and electrons emitted by the work-piece, passes through a minimum value, and that when the work-piece is submitted to an electron beam the focussing distance of which is greater than the optimum focussing distance, said current increases, and then finally tends to decrease when the beam is highly defocussed.

The measure of the ionic and/or electronic currents emitted by the work-piece under the influence of the impact of the electron-beam therefore constitutes a means for determining the optimum focussing of the electron beam in order to obtain the maximum welding efficiency while obtaining optimum penetration of the beam, for a given incident energy and a given travelling speed.

A device for putting into practice the method according to the invention comprises at least one electron gun, means for supporting a work-piece which is to be submitted to a beam issued from said gun, focussing means for said beam, provided with at least one electromagnetic coil, an electrically conducting ring arranged axially with said electron beam, between the work-piece and said focussing beams, said ring being part of a biasing circuit adapted to impart a given polarity to said ring, further comprising means for measuring the current passing through said ring and servo-control means connected to said focussing means, at least one diaphragm or mask arranged around the electron beam between the focussing means and said ring and a grid having a polarity opposed to that of said ring and arranged between the metal part and said ring.

The conveniently biased ring is adapted to collect the current resulting from the ionic and electronic radiations emitted by the work-piece. The diaphragm protects the said ring from the influence of the incident electron beam.

The above disclosed method and device have a certain number of advantages.

One of said advantages results from the fact that it is possible to permanently instantaneously check and control the optimum focussing of the electron beam.

Another advantage is that the permanent checking of the quality of the welding seam can be obtained by means of the reading of the value of the current collected during the welding operation.

A further advantage is that the servo-control of the focussing by the collected current makes it possible to obtain a welding seam having constant characteristics for a varying shooting range of the electron gun. More precisely, the method and device according to the invention make it possible to weld pieces such as tubes having a polygonal cross section, such as square or hexagonal cross section, or plates having varying curvature and the like.

A still further advantage is that it is possible, for a given power of the electronic bombardment to control the depth of the welding seam by changing the travelling speed of the work-piece.

It has further been noticed that the electronic flux comprises on the one hand a flux resulting from the diffusion of a more or less important part of the incident electron beam (retrodiffused flux) and on the other hand a flux of electrons, of lower energy comprising secondary electrons, thermal electrons and electrons resulting from the vaporization of the metals which are melted by the electronic bombardment. Furthermore, for most of the usual metals and for the energies involved in electronic bombardment, merely 95 percent of the actual retrodiffused electrons have a spectral repartition of energy comprised between incident primary energy and 10 percent of said latter energy; we have then determined a selection between the actual retrodiffused electrons, the low energy electrons and the ions, which constitutes further features of the invention.

The results achieved according to the invention as generally defined above have confirmed that, as expected, the devices make it possible, on the one hand, and due to the presence of the electrically conducting ring and the grid arranged after said ring on the part of the electron beam, to collect as well the ionic flux as the electronic flux, and on the other hand, by acting on the biasing of the grid to modify the composition of the flux collected on the ring. It was not possible to collect separately and simultaneously by means of said ring the ionic and electronic fluxes, with the result that the practical control range of the device was relatively narrow and difficult to achieve for maintaining the optimum focussing position. On the contrary, the method and device comprising the features to operate the selection between the different electrons and the ions make it possible to obtain a much wider range for a desired control, which is much easier to maintain.

According to such further feature the electronic flux of high energy, the electronic flux of low energy and the ionic flux respectively diffused and formed under the action of the impact of the electronic beam on the work-piece are collected and separated. The electric currents generated by said fluxes are individually measured, and the measured values relating to the electronic current of high energy are used for controlling the focussing of the electron beam as function of the minimum value of said electronic current of high energy, whereas the other current values may be used for all other control operations.

A device for putting into practice this further feature comprises on the one hand a collector formed of a grounded, cylindric casing attached to the focussing means, centered on the part of the incident electronic beam emitted by the electronic gun, provided in its base with a central aperture and an annular aperture centered on said part and closed by an insulating cover providing central hole, coaxial with said part of said incident electron beam, said holes in the base part and in the cover being connected by a tube of the same diameter, a circular ring forming a first electrode placed against the cover opposite the circular opening therein, a second electrode arranged obliquely on the axis of the beam path and a third electrode parallel with said second electrode, said second and third electrodes forming together an annular, conical passage coaxial with said beam path, and further being electrically insulated from said casing, and on the other hand several control means connected to said first electrode and to said focussing means through first and second grounded measuring means connected to said first electrode and to said third electrode respectively, and means for biasing negatively the first electrode and positively said third electrode.

Said second and third electrodes are preferably in the shape of conic frustums having the same axis of revolution, the mean intermediary conical surface of which has an apex coinciding with the apex of the incident beam on the work-piece.

According to a further feature of the invention the control of the fusion of a metal bar for the obtention of metal ingots, on the one hand and the maintaining of the liquid phase in the top of the mold receiving the molten metal, on the other hand, are made particularly easy, whereby the metal bar is rotated around its axis to regularize the melting.For this purpose, use is made of two associated devices as just above described, one of said devices being arranged on the path of the electron beam which impacts on the end of the metal bar and the other is arranged on the path of the electron beam which impacts on the meniscus of the liquid phase formed at the upper part of the ingot in the mold, in such a manner that the low energy electrons emitted by the liquid phase are intercepted by the third electrode of the second device and the electrons which are retrodiffused are intercepted by the first electrode of the first device, the servo-connections between said devices and the focussing means being such that the focussing means — which are also called deflecting means— do change the proportion between the energies received by the bar and the ingot mold so as to preserve a sufficiently liquid meniscus whereas the servo-control of the second device is controlled to cause the regular melting of the bar.

The invention is illustrated, without being limited, by the appended drawings in which :

FIG. **1** is a diagramatic representation of a preferred embodiment of a device for putting the invention into practice;

FIG. **2** is a diagram showing the variation of the intercepted current and the depth of welding seam in a stainless steel part, respectively, as a function of the focussing of the electron beam for a low energy of said beam;

FIG. **3** is a diagram similar to that of FIG. **2** for an average energy of the electron beam;

FIG. **4** is a diagram similar to that of FIG. **2** for a high energy of the beam;

FIG. **5** is a diagrammatic representation of a device for the control of the focussing of the electron beam according to the invention, for welding or piercing purposes.

FIGS. **6***a*, **6***b* and **6***c* are diagrams showing respectively the variations of the current resulting from the flux of low energy electrons, from the flux of retrodiffused electrons and of the ionic current as a function of the focussing of the electron beam;

FIG. **7** is a tri-dimensional diagram showing the variations of the current resulting from the flux of low energy electrons as a function of the focussing current for various powers of the electron beam;

FIG. **8** is a diagram similar to that of FIG. **7** showing the variations of the current resulting from the flux of retrodiffused electrons of substantially high energy;

FIG. 9 is a diagram comparing the variation of the current resulting from the flux of retrodiffused electrons of substantially high energy as a function of the focussing current (upper part) with the aspect of the corresponding welding seam (bottom part);

FIG. 10 is a diagram showing the ratio between the current Iro, resulting from the flux of retrodiffused electrons in the case of a much too short focussing, and the current Ir, resulting from flux of retrodiffused electrons of relatively high energy for a correct focussing as a function of the depth of the weld obtained for various speeds of relative movement between the electron beam and the work-piece;

FIG. 11 is a diagrammatic view of the device according to the invention applied to the control of diffusion of a metal bar and to the maintaining of the liquid phase in the mold receiving the molten metal;

As shown in FIG. 1, the device according to the invention comprises a ring **1** negatively biased by means of an electric source **2**. Said ring is placed between a grid **3** positively biased a few tens of volts by means of an electric source **4**, and a diaphragm **5** grounded at **6**. The device for measuring the current intercepted by ring **1** comprises a voltmeter **7** of known type connected in parallel with a resistor **8** included in the circuit of ring **1**, whereas a servo-control device **9** of known type, fed the current intercepted by ring **1** is connected to a focussing device, e.g., a converging electromagnetic coil for the electron beam **11** issuing from an electron gun **13**. The connection between the servo-control system **9** and the focussing device **10** is shown by a dotted line. The work-piece **12** which is to be welded is connected to ground **6** and is so placed as to be conveniently heated by the electron beam **11** issuing from gun **13**.

The above described device operates as follows.

Once the distance between gun **13** and work-piece **12** has been approximately set, and the welding power as well as the travel speed of the work-piece having been selected, the electron gun is put into operation. When the energy involved is high, the impact of the electron beam **11** on work-piece **12** produces an ionic and electronic radiation which is collected in part by ring **1**. The resulting electric current having an intensity I is fed to the servo-control device **9** which controls the focussing device **10** until the optimum focussing fo, corresponding to intensity I_m (FIG. **4**), is obtained.

During the welding operation,any variation of the focussing due to a variation of the welding distance causes a variation of the current radiated by work-piece **12**, and consequently an immediate response of the servo-control device **9** which in turn causes a modification of the focussing distance until a new optimum value thereof is obtained.

The operation of the device in case of low and average powers of the electron beam is fully comparable.

When the current collected by ring **1** is represented by a curve as a function of the focussing distance, it appears in all cases that said current passes through a minimum valve corresponding to the optimum focussing distance.

In FIGS. **2–4**, the value of the current I collected by ring **1** has been plotted for various powers of the electron beam in mA as ordinates, as well as the welding seam depth *e* in mm in a stainless steel-work piece. The focussing distance *f* of the electron beam has been plotted as abscissae in arbitrary units.

In each case the power of the electron beam is considered in respect to the travel speed of the work-piece.

In the case of FIG. **2**, said power corresponds to an energy contribution of 0.35 Kilojoule per cm. It may be seen that, in this case, current I first has a negative value corresponding to a much too short focussing distance, then reaches a positive value which increases up to a maximum I_{M_1} when the focussing distance is near the optimum value fo . Current I then passes through a minimum I_m which corresponds to the optimum focussing distance fo , then to a second maximum I_{M_2} when the focussing distance becomes greater than the optimum value. Finally, when the focussing distance becomes much greater than the optimum value a variation of current I is obtained which is substantially comparable, in the reverse direction, to the variation which takes place when the focussing distance is much smaller than the optimum.

As concerns the depth *e* of the welding seam, said depth passes through a maximum e_M corresponding substantially to the minimum I_m of the curve I, and consequently to the optimum focussing distance fo of the electron beam. This explains why the practical possible range of control is relatively narrow and why it is difficult to maintain the best focussing position.

FIG. **3** relates to the case of a mean power of the electron beam, corresponding to a contribution of energy of 1.86 Kj/cm. It may be seen that the minimum I_m of curve I corresponds substantially to the maximum depth e_M of the welding seam, and consequently to the optimal focussing distance fo.

It may be seen that curve I does not in this case have a negative part, this resulting from the fact that, due to the power involved the melting of the work-piece and the emission of positive ions take place even when the focussing distance of the electron beam is far below the optimum value.

FIG. **4** corresponds to the case of a high power of the electron beam,corresponding to a energy contribution of 6.3 kj/cm. It may be seen that the minimum I_m of curve I corresponds substantially to the maximum depth e_M of the welding seam, and consequently to the optimum focussing distance fo .

For such a power of the electron beam, the melting of the work-piece being already vary important for small (or high) values of the focussing distance, the curve obtained by measurement of the current is limited to the portion comprised between the two maximums.

The study of FIGS. **2**, **3** and **4** confirms that, whatever the power of the electron beam,there is always a minimum value I_m of the current collected by ring **1**, corresponding to the optimum focussing distance fo .

In the modifications shown at FIG. **5**, the control device according to the invention comprises a cylindrical casing **21** having a cover **22** made of an insulating material and a bottom part **23** provided with an annular opening **24**. Casing **21** further comprises an axial tube **25**, both casing **21** and **25** being grounded at **26**.

On the inner face of cover **22** is arranged a circular, flat ring **27** coaxial with **25** and forming a first electrode. Said electrode **27** is connected, on the one hand to a servo-control device **28** of known type for the focussing of the electron beam and on the other hand to a measuring device **29** shunted by a resistor **30**. The servo controlled device **28** is connected through a connection **34** represented by a dotted line to a focussing device **31** for the electron beam **32** issuing from the electron gun **33**. The servo-control device **28**, the measuring device **29** and the resistor **30** are grounded, as shown.

Inside casing **21** is a second electrode **35** of substantially frusto-conical shape coaxial with casing **21**. Said electrode is brought to a negative potential, generally of the order of a few tens of volts, by means of generator **36** which is on the other hand grounded through resistor **37**.

A third electrode **38** of frusto-conical shape, coaxial and parallel with electrode **35** is also arranged inside casing **21**, said electrode **38** being brought to a positive potential, generally of the order of few tens of volts, by generator **39** which is grounded through resistor **40**.

The work-piece is diagrammatically shown at **41** under the influence of the impact of the electron beam **32**, and the reemitted beam of particles is shown at **42**.

The above described device apparatus works as follows, in the case of a welding operation taken as example.

Once the distance between gun **33** and work-piece **41** has been approximately established, and once the energy of the electron beam per cm, i.e., the welding power as a function of the travel speed of the work-piece, has been selected, electron gun **33** is set into operation. Incident electron beam **32** causes by impact on work-piece **41** the emission of a reflected beam **42** composed of retrodiffused electrons, low energy electrons and ions. Said beam **42** enters casing **21** through annular opening **24** and then passes in the space comprised between electrodes **35** and **38**.

Due to the electrostatic potential to which said electrodes are brought the ions are deflected by the electrostatic field towards electrode **35**, whereas the low energy electrons are deflected toward electrode **38** and the retrodiffused electrons, having a high energy are less deflected and continue their travel according to a slightly curved path until they reach electrode **27** where they are captured. The three electrodes or captors **35**, **38** and **27** thus gave rise to the production of three currents, i.e., a ionic current Ii which passes to ground **26** through resistor **37**, a current Ie of low energy electrons led to ground through resistor **40** and finally a current of retrodiffused electrons having a relatively high energy, which is fed to servo-control device **28** and/or measured by means of measuring device **29**.

FIGS. **6*a***, **6*b***, **6*c*** show the variations of the intensities of said three currents, as a function of the focussing distance which is plotted in abscissae in arbitrary units. It may be seen that for low energy electrons and for ions (FIGS.**6*a*** and **6*c***, respectively)the corresponding curves have a minimum between two maximums, whereas in the case of retrodiffused electrons of high energy the curve (FIG. **6*b***) only has a minimum. All these minimum values correspond as hereinabove explained to the optimal focussing distance fo of the electron beam. Furthermore, it should be noted that in case of retrodiffused electrons the portions of the curves on either side of the minimum have slope which is very slight if not even inexistent. It may therefore be seen that use of the current resulting from the interception of the retrodiffused electrons by electrode **27** is particularly interesting for the control of the focussing distance of the electron beam to its optimum value; said current is fed, as in the previous example, to the servo-control device **28** which controls the focussing device **31** until the optimum focussing distance fo corresponding to the minimum value of the intensity of the retrodiffused electrons is obtained.

In other terms, during the welding operation taken as example, any variation in the focussing distance resulting particularly from a variation of the welding distance is reduced to a variation in the beam radiated by work-piece **41**, and consequently to an immediate response of the servo control device **28**, which in turns causes modification in the adjustment of the focussing distance until a new optimum value is reached.

The above remarks show the improvements which result from the distinction which is made according to the invention between the retrodiffused electrons having a relatively high energy, the electrons of lower energy and the ions. The control curves obtained according to the general method (FIGS. **2–4**) correspond in fact to a partial superimposition of the three above mentioned currents, which leads to good results especially in the case where the measure defocussing is maintained within relatively narrow limits. The device equipped for selection of the electrons and ions, respectively, gives a representative curve of the intensity as a function of the focussing distance which does not comprise sharp maximums, but only a minimum, and may be used for the focussing control within much wider limits.

FIG. **7** discloses the variation of the current Ie resulting from the flux of low energy electrons as a function of the focussing current for various voltages and powers of the electron beam. As may be seen the series of curves thus obtained forms a valley corresponding to the optimum focussing, which lies between two pronounced crests. This series, which is established for a constant travel speed of the work-piece with respect to the electron beam is obtained by plotting the powers expressed in kilowatts along Y axes. Said series of curves remains the same when the requested energies, expres sed in Kj per cm are plotted along the Y axes.

FIG. **8** shows the variation of the current Ir resulting from the flux of retrodifussed electrons as a function of the focussing current for various voltages and powers of the electron beam. Here also, the series of curves presents a valley corresponding to the optimum focussing; on another hand, there are not crests on each side of the valley as in the preceding case. The control is thus very simplified. In the case of FIG. **8**,the powers plotted along the Y axes may be replaced by the corresponding energies per cm and the Kw replaced by Kj/cm without any change in the general form of the obtained surfaces.

FIG. **9** shows on the one hand (upper part) the influence above the flux of the retrodiffused electrons as a function of the focussing distance when the method according to the invention is applied to welding, and on the other hand (lower part) a section through the corresponding weld. It may easily be seen that to the minimum value of the retrodiffused current Ir corresponds the current of optimal focussing Ifo since the maximum thickness of the welding seam is then obtained, all other conditions being the sames.

FIG. **10** shows the variation of the ratio of the current Iro/Ir resulting from the flux of the retrodiffused electrons in very under-focussed conditions, to the current resulting from the current Ir resulting from flux of retrodiffused electrons in the optimum focussing conditions, as a function of the thickness *e* of the welding seam. The corresponding curve is substantially rectilinear whatever the speed of the workpiece.

By associating the curve of FIG. **10** to the series of curves of FIG. **8**, it is possible to determine the focussing current which should be applied to the focussing coil in order to obtain the piercing or welding of a work-piece at a given depth. Using FIG. **10** the value of ratio Iro/Ir corresponding to the selected depth *e* is obtained. Once said ration is known, it is possible to find in the diagram of FIG. **8** the corresponding point Fo in the valley of the optimum focussing. The focussing current Ifo to be applied may then be found , provided the power Po defined by said point on the diagram, or an equivalent energy per cm is used.

FIG. **11** diagrammatically shows an example of use of the method according to the invention for controlling the melting of a metal bar and maintaining the liquid phase in a mold receiving the molten metal. In this example, the device applied comprises an ingot mold **51** containing the metal in solid phase with a supernatant molten liquid phase **53**. The metal bar **54** which is to be molten is arranged above mold **51**, said bar being in rotation around its axis by an convenient means (not shown). The end of bar **54** has the shape of a cone the angle of which depends, all other conditions being equal, of the heating power. The end of bar **54** as well as the liquid molten metal phase are irradiated by the electron beam **55** emitted by a gun (not shown)through a focussing or reflecting device **56** of any known type. In the region above the liquid metal phase **53** is arranged a first channel **57** at the end of which is a first electrode **58** brought at a positive potential by a source **59** grounded on the other hand through resistor **60**. A millivoltmeter **61**, for instance, measures the difference of potential at terminals of resistor **60**.

Above bar **54** is arranged a second channel **62** at the end of which is a second electrode **63** grounded through a current measuring device **64** such as a milliamperemeter.

Units **57–58** on one hand, **62–63** on the other hand may be advantageously each replaced by a device according to FIG. 5.

Such an equipment operates as follows.

The low energy electrons emitted by liquid phase **53** are intercepted by electrode **58** after having passed through channel **57**, and produce a current Ie detected by voltmeters **61**.

The electrons retrodiffused from bar **54** are intercepted by electrode **63** and the resulting current Ir is measured by milliamperemeter **64**.

To measuring device **61** is connected in the same manner as in the above described examples, a servo-control device **65** controlling the deflector **56** for the electron beam in such as manner that said system modifies the ratio of energy received by bar **54**, on the one hand, and ingot mold **51**, on the other hand, in order to maintain the metal phase **53** in a sufficient liquid states.

In the same manner, a servo-control device **66** is associated with measuring device **64** to control the speed of progression of bar **54** in order to obtain a regular melting of said bar.

What we claim is:

1. A method for controlling the focussing of an electron beam issued from an electron gun and impacting on a metal part, for an at least partial melting operation, comprising generating an electron beam, positioning a metal part in a path of the electron beam intercepting at least one of the ionic and electronic currents retrodiffused from said metal part as a result of the impact of said electron beam, separating the rediffused ionic and electronic currents from secondary electrons emitted from the metal part, measuring said currents retrodiffused from said metal part as a result of the impact of said electron beam, and servo controlling the focussing of said electron beam as a function of a value of the currents to bring said value to a minimum.

2. In a method for controlling the focussing of an electron beam issued from an electron gun and impacting on a metal part to be at least partially melted, comprising generating an electron beam, positioning a metal part in a path of the beam, detecting ionic and electronic currents radiated and retro-diffused by said part, intercepting and separating electron flux of high energy, electron flux of low energy and ion flux respectively diffused and generated by the impact of said beam, intercepting the high energy electron flux, creating electric currents with the high energy electron flux, measuring value of electric currents which are created by said high energy electron flux, and servo-controlling focussing of said electron beam as a function of said value of the currents to bring said value to a minimum.

3. In a device for controlling focussing of an electron beam issued from an electron gun and impacting on a metal part, the improvement comprising focussing means adjacent the electron beam having at least one electromagnetic coil for focussing the electron beam, an electrically conducting ring positioned between the focussing means and the metal part and axially aligned with the electron beam, a biasing circuit connected to the ring and adapted to impart a given polarity to the ring, measuring means connected to the ring for measuring current passing through the ring, and servo-control means connected to the measuring means and to the focussing means, a diaphragm mounted between the focussing means and the ring and arranged around the electron beam for shielding the ring from the focussing means, a grid positioned between the metal part and the ring and arranged around the electron beam, and a grid biasing circuit connected to the grid for imparting to the grid a polarity opposed to a polarity of the ring.

4. In a device for controlling focussing of an electron beam issuing from an electron gun and impacting on a metal part for welding, piercing or cutting the metal part, the improvement comprising the combination of an electron gun for producing an electron beam, beam focussing means adjacent the electron gun for focussing the beam on the metal part, a cylindrical casing arranged around the electron beam emitted by the electron gun, the casing having a space with a central opening centered on the beam, a cover positioned adjacent an upper portion of the casing between the base and the focussing means, the cover having a central opening encircling the electron beam, a tube positioned between the central opening in the cover and the central opening in the base, and leaving an annular opening between the tube and the base, a circular ring forming a first electrode connected to the cover on a side thereof toward the base, second and third spaced parallel electrodes obliquely arranged with respect to the electron beam outward of the tube and between the first electrode and the base, whereby a space between the second and third electrodes is aligned with the annular opening and the first electrode, biasing means connected to the first electrode and to the third electrode for negatively biasing the first electrode and positively biasing the second electrode, measuring means connected to the first electrode for measuring current passing through the first electrode and control means connected to the first electrode and to the measuring means and to the focussing means for changing the focussing means to produce a minimum value in the measuring means.

5. The device according to claim **4** in which the second and third electrodes have shapes of conic frustums having the same axis of revolution and having an imaginary means intermediary conical surface which has an apex coinciding with the incident electron beam on the metal part.

6. A device to simultaneously control the melting of a metal bar and the maintaining of a liquid phase of the metal in a mold comprising an electron gun for producing an electron beam directed toward a metal bar and a surface of liquid metal within a mold, focussing means positioned adjacent the beam spaced from the metal bar and from the mold, a first electrode spaced from a surface of liquid metal in the mold and a diaphragm positioned between the electron beam and the first electrode and oriented in a direction of the surface for exposing the first electrode to radiations from the surface, current measuring means connected to the first electrode and servo means connected to the current measuring means and to the focussing means for focussing the electron beam to produce a minimum current in the first electrode, and a second electrode positioned opposite from the metal bar and shielding means adjacent the second electrode for shielding the electrode from the focussing means and from the electron beam, second measuring means connected to the second electrode and second servo control means connected to the second measuring means, and bar advancing means connected to the metal bar and to the second servo control means for advancing the metal bar at a rate commensurate with maintaining measured current in the second electrode at a minimum.

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