DEFLECTING SYSTEM FOR CHARGE CARRIER BEAMS

Filed Aug. 21, 1962

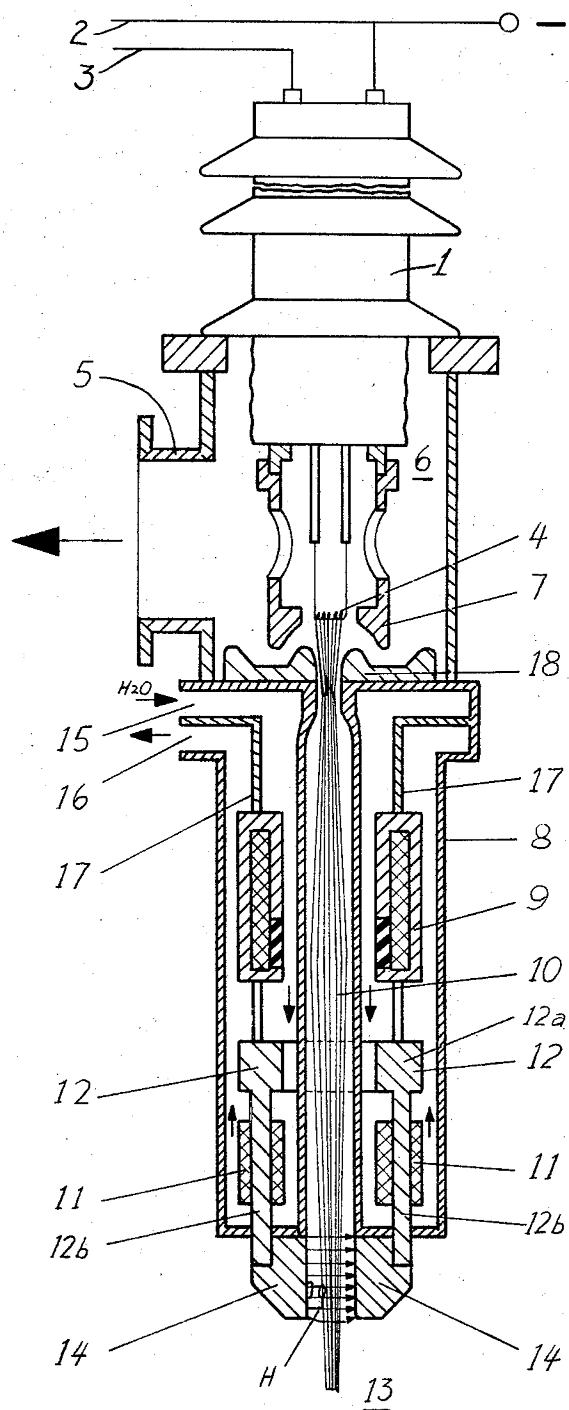

FIG. 1

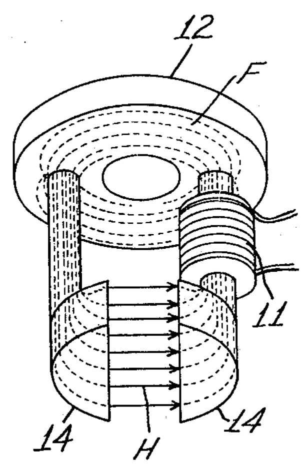

FIG. 2

INVENTOR
WALTER DIETRICH
BY Burgess, Dinklage & Sprung
ATTORNEYS

United States Patent Office

3,312,858

Patented Apr. 4, 1967

3,312,858

DEFLECTING SYSTEM FOR CHARGE CARRIER BEAMS

Walter Dietrich, Hanau am Main, Germany, assignor to W. C. Heraeus G.m.b.H., Hanau am Main, Germany, a corporation of Germany

Filed Aug. 21, 1962, Ser. No. 218,282
Claims priority, application Germany, Aug. 31, 1961, H 39,145
6 Claims. (Cl. 315—27)

The present invention relates to an electromagnetic deflecting system for charge carrier beams, especially of electron guns for electron beam melting furnaces or electron beam evaporators.

In recent times, the source of energy employed for electron beam melting and evaporating apparatus has been provided in the form of electron guns. Such electron guns are built and installed in or on the respective apparatus as compact units which permits them to be easily exchanged as accurately adjusted self-contained systems. In the operation of apparatus of this type it becomes very frequently necessary to deflect the electron beam from the axis of the electron gun, for example, when the focussed electron beam is to be used for scanning a larger surface. This applies particularly to electron beam melting apparatus when the same electron gun system is to be employed for crucibles of different diameters without requiring, for example, the axis of the electron gun to be displaced mechanically.

It is known in general that the direction of an electron beam may be changed under the influence of a magnetic field and that for this purpose the magnetic field is preferably arranged so as to extend vertically to the direction of the electron beam. For particular reasons it is also more advisable in apparatus of the above-mentioned type to apply this principle of changing the direction of the electron beam by means of a magnetic field than to deflect it by means of an electric field.

Although various kinds of electromagnetic deflecting systems for electron beams are known, these systems are unsuitable for electron guns for electron beam melting furnaces or evaporators since the electron beam would then be deflected before emerging from the gun unit into the melting or evaporating chamber with the result that the high-amperage electron beam itself may then damage its own deflecting system.

It is an object of the present invention to provide an electromagnetic deflecting system for charge carrier beams especially of electron guns of electron beam melting furnaces or electron beam evaporators which overcomes the above-mentioned disadvantage of the known systems and which for this purpose consists of one or more solenoids with a ferromagnetic core, the two ends of which project downwardly from the gun unit and there form the two magnetic poles which produce the magnetic field for deflecting the charge carrier beam.

According to a preferred embodiment of the invention, the two ends of the core are either made of a special design, for example, in the form of pole pieces, or separate pole pieces of a ferromagnetic material are secured to the two ends of the ferromagnetic core. It has also been found advisable to insert the deflecting system together with one or more magnetic lenses into a suitable cooling medium, but in a manner so that the projecting ends of the ferromagnetic core are located outside of the cooling medium. The cooling medium preferably circulates within a hermetically sealed casing which also encloses the solenoids of the lens and the deflecting system.

The deflecting system according to the invention has among others the advantage that, even when deflected at wide angles, the charge carrier beam cannot possibly damage the deflecting system and its surrounding casing. Furthermore, the arrangement according to the invention permits the entire gun unit including the deflecting system to be easily exchanged. Even at large deflecting angles there is no need for any mechanical displacement of the axis of the gun unit. The deflecting system according to the invention has the further advantage that solenoids with a large number of ampere turns may also be installed within the gun unit and will thus be well protected without affecting the freedom of movement of the charge carrier beam when being deflected.

The objects, features, and advantages of the invention will become more clearly apparent from the following detailed description and the accompanying drawing in which:

FIG. 1 is a schematic illustration, partly in section, of an electron gun provided with a deflecting system according to a preferred embodiment of the invention.

FIG. 2 is a perspective view of the deflecting system in FIG. 1 illustrated apart from the electron gun assembly, and modified by the removal of one of the solenoid coils shown therein.

The electron gun as illustrated in the drawing is provided with an insulator **1** through which the conductors **2** and **3** for the hot cathode **4** are passed, upon which a high negative potential is applied and which is mounted together with the modulating electrode **7** within a chamber **6** which may be evacuated through the suction flange **5**. Chamber **6** is connected to a casing **8** in which a magnetic lens **9** is mounted. This casing **8** also contains the deflecting system for the charge carrier beam which consists of the two solenoids **11** and the ferromagnetic core **12**, the upper part of which above the solenoids **11** is made of an annular shape so that the focussed beam **10** can pass through the opening in this upper part. The lower ends of core **12** underneath the casing **8** which extend into the melting or evaporating chamber **13** carry pole pieces **14** of a ferromagnetic material between which the magnetic field H is produced which causes the deflection of the charge carrier beam **10**. For a precision adjustment of the direction in which the beam is deflected, it is possible to turn the pole pieces **14** slightly about the axis of the beam. Casing **8** is provided with an inlet line **15** and an outlet line **16** for a coolant and also with a coolant baffle **17**. The charge carrier beam is accelerated by the electric field which is formed between the cathode **4** and the anode aperture **18**. By varying the magnetic field H it is possible to deflect the charge carrier beam to different angles.

Although my invention has been illustrated and described with reference to the preferred embodiment thereof, I wish to have it understood that it is in no way limited to the details of such embodiment but is capable of numerous modifications within the scope of the appended claims. Thus, for example, instead of providing the ferromagnetic core **12** with an annular part, it may also be provided with a bore for the passage of the charge carrier beam. The pole pieces or lower ends of the ferromagnetic core may also be designed so that the cross-sectional shape of the deflected beam will be either equal or different from the cross-sectional shape of the beam before it is deflected. Thus, for example, a beam which has a circular cross section before it is deflected may after being deflected be altered by pole pieces of a suitable design to form a beam of an elliptic cross section.

As can be more readily noted from FIG. 2, taken in conjunction with FIG. 1, the electron beam deflection system of the invention operates by creating a magnetic flux interacting with the electron beam to angularly deflect it with respect to its original axis or path within the gun. This deflection is performed at a location on the beam path just prior to the point where the beam emerges from the gun to eliminate the hazard of the deflected beam striking and thereby damaging any part of the gun or the deflection system itself. The magnetic flux which effects such angular deflection is created by one or more solenoids **11** and a permeable core structure including a ferromagnetic core **12** supported by the electron gun, and a pair of ferromagnetic pole pieces **14**. The core **12** is a central apertured portion **12***a* disposed to accommodate the free passage therethrough of the focused electron beam traveling along a path defined by its original axis, and a pair of projecting end members **12***b* extending from the apertured portion **12***a* in the direction of electron beam travel and in substantially parallel spaced relation thereto. The pole pieces **14** are each mounted to the free end of a projecting end member **12***b*, and are disposed in opposite spaced apart relation to each other to define a gap accommodating the passage of the electron beam therethrough.

A magnetic flux circuit, illustrated by dashed flux lines F, extending through the central apertured core portion **12***a*, both projecting end members **12***b*, both pole pieces **14**, and across the gap defined by the spacing of said pole pieces **14**, is established by either a pair of solenoids **11** as in FIG. 1, or by a single solenoid **11** as in FIG. 2 mounted on one of the projecting end members **12***b* and disposed for connection to a source of electricity (not shown) for controllable energization thereby. As is well known in the art, the degree of angular deflection experienced by the electron beam will be dependent upon the strength of the magnetic field H produced by flux lines traversing the gap between the pole pieces **14**, and thus, by regulating the current flowing through a single solenoid **11**, or through a pair of solenoids **11**, one mounted on each projecting end member **12***b*, the angular deflection of the emergent electron beam can be correspondingly regulated.

In many applications of the invention, it will be expedient to use two of such solenoids **11** as exemplified by FIG. 1, since with two solenoids **11**, the current flow through each can be regulated to produce a desired direction and intensity of the gap field H as needed to achieve a particular angle of electron beam deflection.

Having thus fully disclosed by invention, what I claim is:

1. In an electron gun wherein a focused electron beam is generated and emerges therefrom, a deflection system for controlling the angular deflection of said emergent electron beam with respect to its original axis, which comprises

(a) A ferromagnetic core supported by the electron gun and having a central apertured portion disposed to accommodate the free passage therethrough of the focused electron beam travelling along a path defined by its original axis, said core having a pair of projecting end members extending from said apertured portion in the direction of electron beam travel and in substantially parallel spaced relation thereto,

(b) A pair of ferromagnetic pole pieces each mounted to the free end of a projecting end member of said ferromagnetic core and disposed in opposite spaced apart relation to each other to define a gap accommodating the passage of the focused electron beam therethrough,

(c) A solenoid mounted on one of the projecting end members of said ferromagnetic core and disposed for connection to a source of electricity for controllable energization thereby to establish a magnetic flux circuit extending through the central apertured portion of the core, both projecting end members thereof, both pole pieces and across the gap defined by the spacing of said pole pieces for interaction with the focused electron beam passing therethrough to correspondingly and controllably deflect said beam as it emerges from the electron gun past said pole pieces.

2. The deflection system according to claim **1** including a pair of solenoids, each mounted on a projecting end member of the ferromagnetic core and disposed for connection to a source of electricity for controllable energization thereby to establish said magnetic flux circuit.

3. The deflection system according to claim **1** wherein said pole pieces are integrally constructed with their corresponding projecting end member of the core.

4. The deflection system according to claim **1** wherein the apertured portion of the ferromagnetic core is annular in shape, and said core and solenoid are supported within a casing provided in the electron gun, and including means for circulating a coolant through said casing and around said core and solenoid.

5. The deflection system according to claim **1** in combination with a magnetic lens for focusing the electron beam, said magnetic lens being disposed in the path of the electron beam ahead of the deflection system.

6. The deflection system according to claim **2** wherein the apertured portion of the ferromagnetic core is annular in shape, and said core and both solenoids are supported within a casing provided in the electron gun, and including means for circulating a coolant through said casing and around said core and solenoids.

References Cited by the Examiner

UNITED STATES PATENTS

2,418,349	4/1947	Hillier et al.	313—84
3,008,044	11/1961	Buchhold	250—49.5
3,182,195	5/1965	Fuchs	313—77 X

OTHER REFERENCES

Von Ardenne, M., and Schiller, S.: Ein 45-KW-Elektronenstrahl-Mehrkammerofen Fur Das Schmelzen Und Giessen Beliebiger Metalle, in "Kernergie," page 510, June, 1960.

DAVID G. REDINBAUGH, *Primary Examiner.*

JOHN T. BURNS, *Examiner.*

G. HARRIS, Jr., T. A. GALLAGHER, *Assistant Examiners.*