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R. C. HOLLAND

3,406,273

MAGNETIC VAPOR DEFLECTOR FOR AN ELECTRON BEAM

Filed Dec. 14, 1966

2 Sheets-Sheet 1

FIG. 1

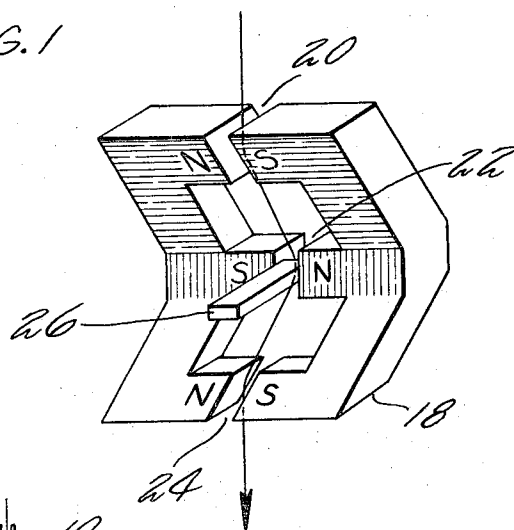


FIG. 2

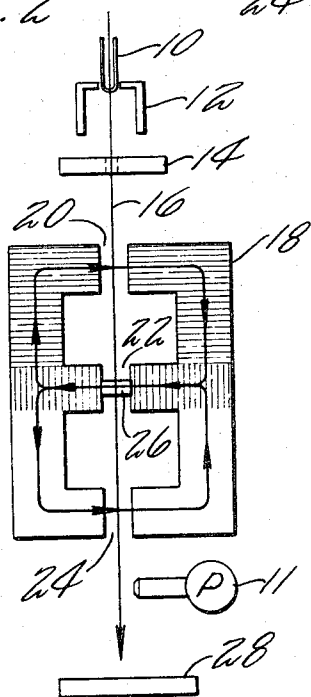
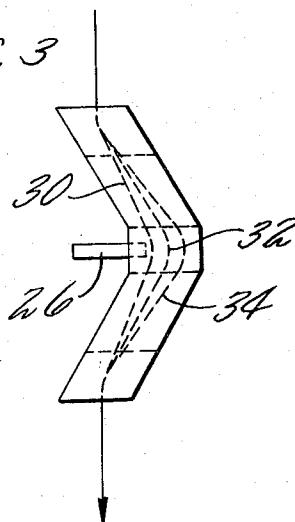


FIG. 3



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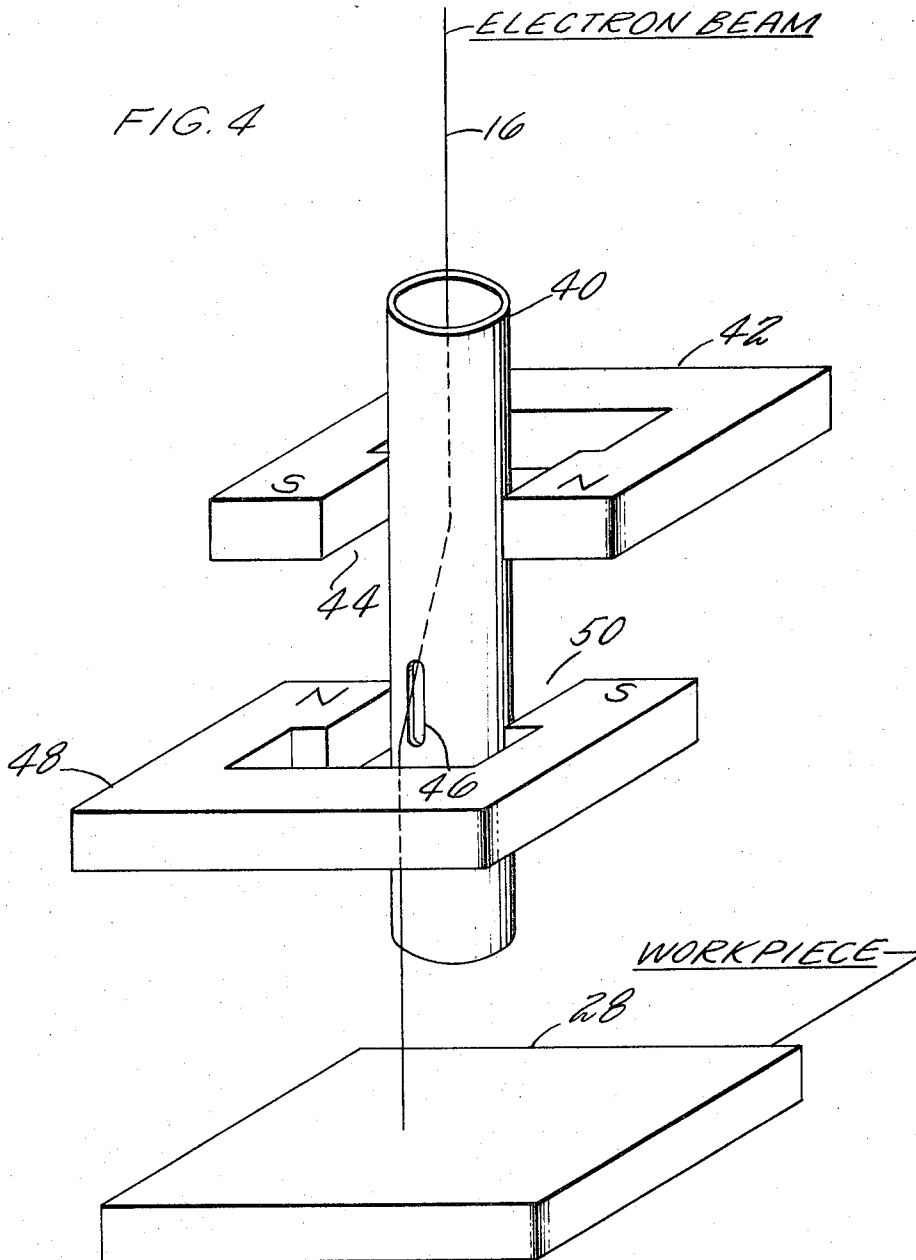
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MAGNETIC VAPOR DEFLECTOR FOR AN ELECTRON BEAM

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5 Claims. (Cl. 219-121)

This invention relates to a device for the protection of an electron gun. More specifically it relates to a device for magnetically deflecting an electron beam about a structure interposed between the beam generating source and the workpiece at which the electron beam is directed.

Since the vapors emanating from a workpiece worked by an electron beam travel in essentially straight lines it is desirable to deflect the beam about a structure interposed between the electron source and the workpiece. With such arrangement, the damaging effect of the vapors on the electron source is reduced since the vapors tend to deposit on the interposing structure and cannot reach the electron source.

This invention offers a versatile, low cost magnetic deflection system for eliminating the straight line of sight path between the workpiece and an electron beam source. In the most elementary form of deflection systems for eliminating the line of sight, single deflection coil for bending the electron beam a specific angle of θ is used. To maintain the deflection of the beam constant while the beam accelerating voltage varies, a complicated electrical deflection circuit is required to hold the beam on the desired spot on the workpiece. Any ripple or instability of the deflection signal or of the accelerating voltage will produce undesired movement of the electron beam. Unless the circuit for the deflecting coil can respond fast to beam accelerating voltage changes, the electron beam will be deflected whenever any transient condition occurs. A major disadvantage to these prior art beam bending devices is the cost and complication of the necessary electronic controls.

It is therefore an object of this invention to provide a magnetic deflecting system which eliminates the line of sight between the cathode and the workpiece.

It is another object of this invention to produce a magnetic deflection system which eliminates the line of sight between the electron beam source and the workpiece and is insensitive to beam accelerating voltage variations.

It is still another object of this invention to produce a deflection system for an electron beam wherein an electron beam is magnetically bent around a vapor deflector.

It is a further object of this invention to produce a deflecting system for an electron beam wherein an electron beam is passed through a vapor deflector.

These and other objects of this invention will become more readily apparent upon a study of the two embodiments which are more specifically described below. In one embodiment the line of sight between the electron gun source and the workpiece is eliminated by using three permanent magnets to deflect the beam away from its original axis around a vapor deflector and then back again along the original axis. The first magnetic field produces a deflection angle of θ , the second magnet bends the beam back towards the axis with an angle of -2θ and the third magnet bends the beam with an angle of θ along the axis of the beam.

My invention may be better understood and its numerous advantages will become apparent to those skilled in the art by reference to the accompanying drawing, wherein like reference numerals refer to like elements in the various figures, and in which:

FIGURE 1 is a sectional view of a first embodiment of my invention.

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FIGURE 2 is a view of the magnetic path through the magnetic bending device of the first embodiment.

FIGURE 3 is a side view of the first embodiment.

FIGURE 4 is a second embodiment of my invention.

The electron beam is a useful tool for the working of materials, for instance, in cutting, drilling or welding of metals in a vacuum. Such electron beam apparatus are well known in the art and one that may be used in connection with this invention is described in the patent to Steigerwald, 2,987,610. The working of materials in a vacuum with an intense electron beam is usually accompanied by vaporization of the materials that are being worked. Such evaporation will cause damage to the cathode from which the electrons are produced if they are permitted to reach the cathode region. Various schemes have been proposed to reduce the vapor flow to the cathode region, see, for instance, the patent to Opitz et al., 2,944,172.

In FIGURE 2 there is shown a cathode 10 for generating a beam of electrons and a control electrode 12 and a grounded anode 14 for producing an accelerating field for the electrons generated by the cathode. The electron beam 16 is focussed and then made to pass through a magnetic deflection device 18. The magnetic deflector 18 consists of two oppositely facing E-shaped magnetic structures having three gaps 20, 22 and 24. The magnetic field is produced by permanent magnets although it is, of course, possible to provide the magnetic field with the proper magnetization current from coils mounted on the E cores. The cores are E-shaped but also have a third dimensional profile as is shown in the side view of FIGURE 3.

Referring to FIGURE 1, the gaps 20, 22 and 24 between the pole faces ordinarily provide an unobstructed passage for the vapors emanating from the workpiece below the magnetic structure 18, and therefore a vapor deflector 26 is mounted as shown. This deflector can take any shape desired as long as it interrupts the line of sight from the cathode 10 to the workpiece 28. The vapor deflector 26 may even partially extend within the gap 22 but will then have to be of such material that it does not interfere with the magnetic flux within this gap. The vapor deflector 26 also may be so shaped to substantially close off the vacuum chamber within which the magnetic structure 18 is mounted. When the vapor deflector is so shaped, only gap 22 provides a free passageway for the electron beam 16 to reach the workpiece 28 and by placing the pumping system 11 for evacuating the chamber in which the cathode control electrode is located between the magnetic structure 18 and the workpiece, the amount of vapor entering the cathode region will be substantially reduced. It is also desirable to render the vapor deflector 26 conductive on the side facing the electron beam so that any stray electrons that may strike the vapor deflector will not cause an undesirable accumulation of charge and avoid undesirable deflections.

In FIGURE 3 a side view of the magnetic structure 18 shows how the deflector 26 interrupts the line of sight between the electron beam source and the workpiece and shows three different paths 30, 32 and 34 which the electron beam may take to pass around the vapor deflector. These three paths indicate the different bending angles of the electron beam as a result of variations in the accelerating potential.

The angle of deflection θ caused by a magnetic field is proportional to the accelerating voltage by the formula

$$\theta = \frac{K}{[V(1+10^{-6}V)]^{1/2}}$$

where K is a constant related to the field strength and size of the magnet, and V is the beam potential in volts.

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The range of beam potential over which the device will operate is limited to a range over which θ is kept to excursions within the range of influence of the gaps. If the beam potential did not stay within a given design range, the second gap could be missed by the beam and cause serious damage to the machine structure. The three pole faces must be matched so that starting from the point at which the electron beam enters the structure 18, the beam is deflected θ degrees at the gap 20 and -2θ degrees at gap 22 and again $+\theta$ degrees at gap 24. The total resultant beam deflection is zero and the advantage of this device is that it is independent of the variations in the beam potential. Thus, as is illustrated in FIGURE 3 with the highest beam potential, the electron beam is deflected along a path as is indicated by 30. At some intermediate beam potential, the beam will follow the path 32 and with the lowest beam potential it is deflected along path 34.

The flux paths generated in the magnetic structure 18 are shown in FIGURE 2. In order to have the same angular deflections at gaps 20 and 24, the flux in these gaps have the same direction whereas the flux in gap 22 is reversed with approximately twice the magnitude in order to obtain a reverse deflection.

FIGURE 4 shows an electron beam 16 entering a tube 40. The tube 40 is made of such material that it passes the magnetic field of the magnet 42 and is positioned in the gap 44 of the magnet 42. The magnetic field generated by the magnet 42 causes a deflection of the electron beam towards the slot 46 cut into tube 40. Thereby the electron beam passes through the slot 46 and enters the magnetic field generated by the magnet 48. Magnet 48 has a gap 50 through which the electron beam 16 passes when it emerges from the slot 46. The tube 40 extends also through the gap 50 to below the magnet 48 and is closed at the end facing the workpiece 28. It thus can be seen that if the magnetic field of magnets 42 and 48 are oriented in opposite directions to cause deflection of the beam 16 in opposite directions, the beam 16 travels towards the workpiece along an axis parallel to the original line but offset therefrom at some distance depending upon the magnitude of the field strength in the magnets and their size. It is of course possible to replace the permanent magnets 42 and 48 with magnets excited by a D.C. current through a coil wound on a magnetic core.

It can therefore be seen that the embodiment of FIGURE 4 eliminates a direct line of sight path for the vapors emanating from the workpiece area to the cathode 10. The slot 46 is made sufficiently large to accommodate deflection angle differences caused by variations in the accelerating potential of the electron beam.

It is to be understood that the invention is not limited to the specific embodiments herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. Apparatus for working materials with a beam of charged particles comprising:

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means for generating a beam of charged particles, means for directing and focussing said beam along a first line towards the materials to be worked, a vapor deflector interposed across the first line between the beam generating means and the materials, a pair of oppositely disposed E core magnetic beam deflectors with magnetic poles of opposite polarity facing one another across a predetermined gap, said pair of E core beam deflectors positioned with the vapor deflector adjacent the central gap, where the magnetic poles across the upper gap nearest the beam generating means deflect the beam in a first direction away from the first line and past the vapor deflector,

where the central magnetic poles of the pair of E cores deflect the beam in a second direction towards the first line,

and where the magnetic poles across the lower gap nearest the materials to be worked deflect the beam substantially parallel to the first line.

2. A device as recited in claim 1 wherein the pair of E cores are shaped

with the portions of the E cores above the central gap bent substantially parallel to the first direction and the upper gap located along the first line,

with the portions of the E cores below the central gap bent substantially parallel to the second direction and the lower gap located along the first line,

and where the vapor deflector is positioned to mask the first line between the upper and lower gaps and shield the beam generating means from vapors traveling from the materials along the first line.

3. Apparatus for working materials with a beam of charged particles comprising:

means for generating a beam of charged particles, means for directing and focussing said beam along a first line towards the materials to be worked, a vapor deflector tube positioned to partially enclose the first line and having a closed end facing the materials and an open end facing the beam generating means,

the tube being provided with an opening along its side, a first magnetic deflector having its poles positioned adjacent the tube for deflecting the beam away from the first line towards the side opening in the tube, a second magnetic deflector having its poles positioned near the side opening to deflect the beam in a direction substantially parallel to the first line.

4. A device as recited in claim 3

wherein the vapor deflector tube has a cylindrical shape.

5. A device as recited in claim 3

wherein the vapor deflector tube is made of a non-magnetic material.

No references cited.

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