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FOCUS CONTROL FOR ELECTRON BEAM HEATING

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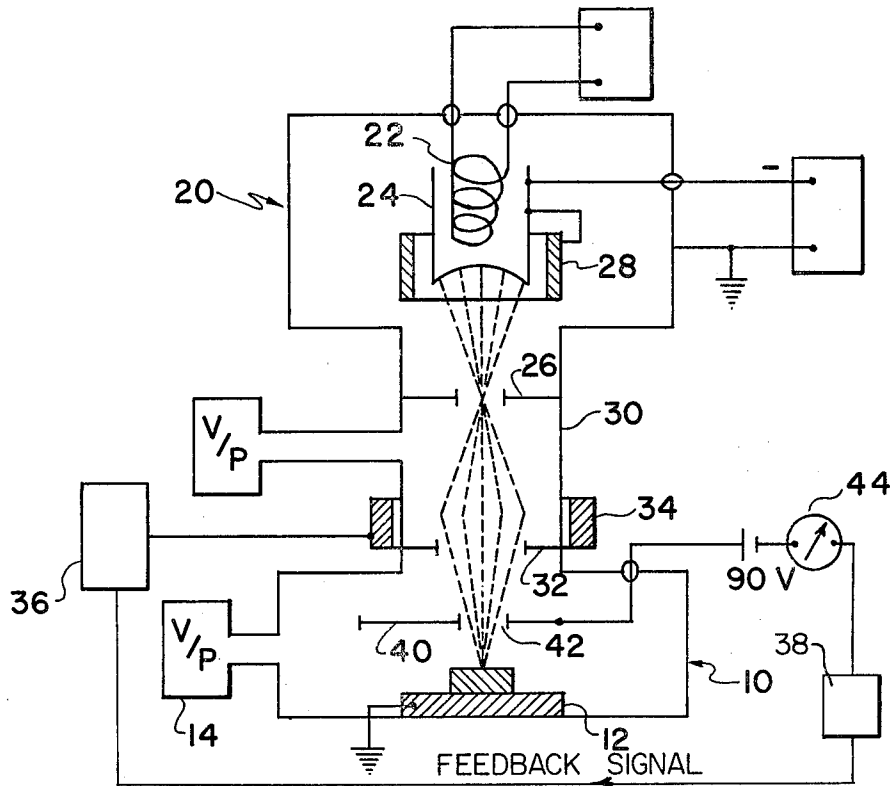


Fig. 1

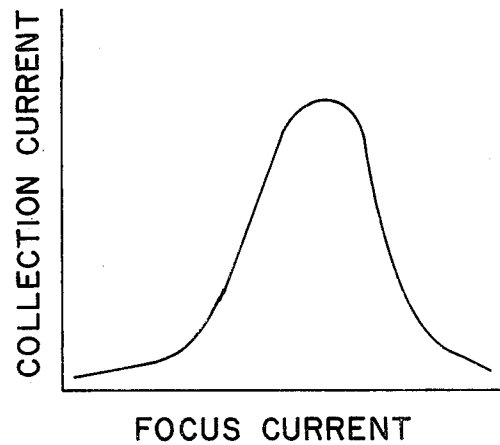


Fig. 2

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BEAM HEATING

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4 Claims. (Cl. 219—117)

This invention relates to an improvement in high vacuum electron beam heating. It is known to heat material by concentrating a charged particle beam such as an electron beam or an ion beam of high intensity on a point or small area of a workpiece in an evacuated chamber. This type of heating, hereinafter referred to as electron beam heating, is of particular utility in such applications as welding reactive metals to produce gas-free welds of extreme purity, etching and drilling.

A principal limitation of electron beam heating is the difficulty of monitoring the focusing of fixed and scanning type beams. This is accomplished by intermittent operation with sample checks between operations or, during operation (through a sight port) by visual inspection of the glow at the work. Both of these techniques are awkward and inefficient.

It is therefore the object of this invention to provide means for monitoring the focus of a high intensity electron beam by sensitive instruments which respond to a parameter of operation which varies as a measurable function of focusing and apparatus for implementing this method, manually and automatically.

In accordance with the invention, reliance is placed on thermionic emission from the work piece. Thermionic emission is very sensitive to temperature and is conveniently detected under the vacuum conditions of electron beam heating processes. An emission pickup electrode is arranged to attract low energy electrons emitted from the workpiece by thermionic emission. This produces a current through the pickup electrode which can be measured to provide a convenient and reliable indication of focus.

It is a further object of this invention to provide an improved high vacuum electron beam furnace with apparatus for monitoring beam focus.

These and further objects will in part be obvious and in part appear hereinafter.

The invention accordingly comprises the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the invention, reference should be had to the following detailed description taken in conjunction with the accompanying drawings which schematically show a preferred embodiment of the invention and wherein:

FIG. 1 is a diagrammatic, partly sectional side view of an electron beam furnace incorporating the features of the instant invention, shown in a preferred embodiment;

FIG. 2 is a curve of collection current vs. focus coil current, indicating the qualitative relation of these parameters.

Referring now to FIG. 1, there is shown an electron beam metal machining furnace incorporating the instant invention. The furnace comprises a vacuum tight chamber 10 having a work support 12 supporting a workpiece to be machined. Reference may be had to U.S. Patent 2,981,823 to Candidus, for discussion of the work support 12. A large capacity vacuum pumping system 14 is employed to evacuate the chamber 10 to pressures on the order of 0.1 micron depending upon the requirements of the particular workpiece.

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The electron gun 20 comprises a filament 22 for heating a cathode 24. The cathode is preferably a concave tantalum or tungsten element. Reference may be had to: Hablani, pp. 42-53 of Proceedings Third Symposium on Electron Beam Technology (Alloyd Electronics Corporation 1961), for further discussion. The indirectly heated cathode is maintained at a high negative bias, on the order of 20 k.v., relative to the anode. An apertured accelerating anode 26 is placed between the cathode and the workpiece. It will be appreciated that the cathode can alternatively be a simple directly heated filament, such as a helix of tungsten wire or a wire hairpin. A focusing electrode 28 surrounds the cathode.

The gun also includes a tube 30 with an apertured partition 32 and a magnetic focusing coil 34 for directing the electron beam to the workpiece while separating the cathode from the workpiece. A plurality of partitions and coils may be provided, as shown in said Candidus patent.

An electrode plate, or grid, 40 is located in the chamber 10 and includes an aperture 42 which is placed in the intended path of the electron beam. The size of the aperture 42 is large enough to allow for minor faults in focusing and/or direction of the beam and allows the beam to pass through uninterrupted. The electrode may, alternatively, be a single loop of wire or the walls of the chamber 10. However, the plate configuration is preferred. The member 40 is biased positive relative to the grounded workpiece to pick up an electron current due to thermionic emission. The collection current, at 90 volts bias and 100 microamperes beam current, ranges from 10 to 50 microamperes, peaking at the point of maximum watt density at the working spot. This current is measured by a meter 44. A decrease in the current reading of meter 44 indicates that the beam is out of focus since thermionic emission will then drop off. When improper focus is noted it can be corrected, by adjusting the focus coil power supply 36. The voltage applied to the collector is not critical beyond a minimal value of 25 volts. This minimum value varies with the position of the collector 40.

FIG. 2 shows a curve of collection current plotted against focus current. Generally, the point of best focus corresponds to the peak of the collection current curve and a decrease in collection current indicate improper focus. Although the signal peak level changes as the work is moved, the peak level still corresponds to maximum watt density at the working spot.

There are several background signals which are unavoidable—secondary emission from the work, X-rays, infra-red rays and negative ions. However, the high temperature sensitivity of thermionic emission gives the electron collection current a distinguishable signal which can be calibrated to indicate proper focus.

It will now be appreciated that the meter 44 may be connected to a feedback circuit 38. Typically, the feedback could send a signal to focus coil power supply 36. Where optimum collection current is off the peak of the curve, an increase or decrease of collector current will indicate the appropriate corrective action. Where optimum collection is at the peak of the curve (which is usually the case) the automatic control must also include phase sensitive means as well as means for detecting a decrease in the magnitude of the collection current. The feedback 38 may be a conventional null seeking circuit with balancing motor (as shown, for example, in Batcher and Moulic, Electronic Control Handbook, Caldwell-Clements, New York, 1946, p. 298) with the feedback signal taken off the shaft of the balancing motor. The feedbacks used in peak seeking radar circuits would also be suitable.

Since certain changes can be made in the above apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in

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the above description shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In an electron beam machine for performing metal machining operations such as welding, melting, etching and the like, wherein a self-accelerated gun emits a beam of electrons to impinge on a small area of the workpiece with a high watt density whereby low energy electrons are thermionically emitted, the improvement comprising: a pickup electrode located in line-of-sight relation to the area of the workpiece subject to impingement by the beam, means for biasing the electrode positive to the workpiece so that the electrode attracts said thermionically emitted electrons and electric circuit means including indicator means connected to said electrode for generating an output signal varying as a function of degree of focus of said beam of electrons.

2. The improved machine of claim 1 wherein the electrode comprises a plate mounted above the workpiece, said plate having an aperture therein to permit passage of said electron beam.

3. In an electron beam machine for performing metal machining operations such as welding, melting, etching and the like, wherein a self-accelerated gun emits a beam of electrons to impinge on a small area of the workpiece

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with a high watt density whereby low energy electrons are thermionically emitted, the improvement comprising: a pickup electrode located in line-of-sight relation to the area of the workpiece subject to impingement by the beam, means for biasing the electrode positive to the workpiece so that the electrode attracts said thermionically emitted electrons and electric circuit means for transmitting an output signal from said electrode varying as a function of the electron current flowing through said electrode, and wherein an electromagnetic focus coil is provided for adjusting the focus of the electron beam downstream of the gun and the improvement further comprises means responsive to the current through said electrode for automatically adjusting the focus of said beam of electrons.

4. The improved machine of claim 3 wherein the electrode comprises a plate mounted between the workpiece and gun, said plate having an aperture therein to permit passage of said electron beam.

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