CURRENT CONTROL FOR A COLD CATHODE
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3 Claims

ABSTRACT OF THE DISCLOSURE

The current in the electron beam of a cold cathode operating in a glow discharge is stabilized by keeping the temperature of the cathode constant. Temperature variations of the cathode and their effect upon the electron beam power and on efficiency are stabilized by controlled cooling of the cathode.

Background of the invention

In the field of cold cathode devices such as disclosed in the copending application by Fernando J. Ferreira entitled, "Annular Hollow Cathode Discharge Apparatus," Ser. No. 414,399, filed Dec. 10, 1964, and assigned to the same assignee, it is desirable that the temperature of the cathode structure be maintained relatively constant for high efficiency operations. When a cold cathode of the type described in the copending application is exposed to an environment wherein gas pressure is kept at a predetermined level, and the appropriate high negative voltage is applied to the cathode with regard to the anode located in the evacuated chamber, a collimated beam of electrons can be produced. The beam of electrons is not produced by the well known thermionic emitting process but rather relies in the case of the hollow cathode, on a plasma enclosed by the cathode or in the case of the contoured cathode primarily by surface emissions produced by impinging particles such as ions. A contoured cathode of this type is disclosed in the copending application to Jack W. Davis entitled "Contoured Cathode," Ser. No. 508,314, filed Nov. 17, 1965 and assigned to the same assignee.

In any of these cold cathodes it is desirable that the temperature be maintained constant or not permitted to rise as the device is operated. With each particular power setting for such a cathode a temperature rise of the structure is unavoidable. When the temperature rises to levels approaching those where a sufficient change in gas density within the cathode occurs, then a drop in the electron beam current results. With rising wall temperatures the neutral gas density within the hollow cathode decreases if gas pressure is maintained constant. The current which is proportional to the gas density then decreases.

Summary of invention

It is therefore an object of this invention to provide a cold cathode current stabilizing device for eliminating temperature effects on the electron beam generated by the cathode.

This is accomplished by a coolant conduit coupled in heat conducting relationship with the walls of the cathode structure and wherein the coolant passing through the conduit has its flow controlled by a valve which in turn is regulated by an error signal. This error signal is indicative of the variations of the actual anode-to-cathode current from a desired value.

Description of the preferred embodiment

In FIG. 1 the control mechanism of this invention is shown. In FIG. 2 the cathode structure assembly is shown.

In FIG. 2 the cathode 10 is enclosed in a chamber 11. In addition the workpiece 12 is located opposite an aperture 14 located in the frontal surface of the cathode 10. The aperture 14 is such that the gas discharge in the chamber is substantially at anode potential except for the region adjacent the hollow cathode 10. A power supply 15 is connected to ground and negatively charges the cathode 10 through a conductor 16. The connection between the supply 15 and the cathode is carefully designed to avoid any arcing adjacent to the negative voltage lead and this may be accomplished for instance, by a high voltage lead-in device described in the copending application by Allan P. Walsh filed Nov. 17, 1965, Ser. No. 508,201, entitled, "Mounting for a Glow Discharge Cathode," and assigned to the same assignee. Surrounding the cathode 10 and the lead-in 16 is a shield 17 which is so spaced from these to suppress the formation of a glow discharge in the gap. In addition, a conduit 18 is shown in cross-section inside the walls of the cathode structure 10. Means for coupling a source of coolant fluid 19 through the tubing device to the conduit 18 is provided. This tubing 20 must be electrically isolated from the cathode structure 10 to avoid carrying the negative voltage of the cathode back to the operator's control console. This may be simply accomplished by allowing for an insulator section near the cathode 10.

The coolant fluid may be clean water which is substantially non-conductive, a requirement to avoid conducting the high voltage to the operator. In series between the source of fluid 19 and the conduit 18 is a valve 21. This valve regulates the flow of fluid through the piping 20 and is, in turn, controlled by actuator 22. Current control may be obtained by varying the pressure or controlling cheater means inside the high voltage supply 15. A desired current reference signal is obtained from a variable resistor 23 which is energized from a DC source and the voltage on the wiper arm corresponds to the desired current. The wiper arm may be ganged to the pressure regulator means 9 for providing a trim-type current control for stabilizing the current as a result of temperature variations. The wiper arm of variable resistor 23 is coupled to a comparator circuit 24. A current sensing device 25 is provided in series or parallel with the lead 16 for determining the actual current flowing therethrough and the output from this current sensing device 25 is applied to the other input of the comparator circuit 24. The output of the comparator is an error signal indicative of the deviation of the actual current from the desired value and this error signal is applied to the actuator 22 to control the valve 21. In this case the polarity and magnitude of the error signal are such that the actuator 22 will control the flow of coolant fluid through the tubing 20 and to the conduit 18, in such a manner as to reduce the error signal to a minimum value.

In FIG. 1 the actual construction of the cathode including the coolant conduit is shown. A perforated or a solid walled hollow cathode device 30 has internal to it a conduit arrangement 18. The conduit is in heat conducting relationship with the walls of the cylindrical hollow cathode structure 30 and is generally placed internal thereto. As shown the conduit 18 is designed to emphasize the cooling of the frontal surface 32 and the back surface 34 of the hollow cathode 30. Two tubes for providing an inlet and an outlet of the conduit 18 are provided. Over the cylindrical cathode fits the insulator 17. The entire structure is suspended from the walls of a chamber or member located in the chamber. Of course hollow cathode
arrangements are possible, for instance with an annular cathode, and a different coolant conduit design could be made, but the effect on the efficiency by maintaining the temperature constant will still be obtained.

The effectiveness of a temperature controlled cathode is confirmed by experimental results. For instance, in a cathode which just had the frontal face cooled and which was operated at 14,000 volts, the beam current increased from 13 ma. to 20 ma. yielding a beam power increase from 100 to 185 watts or 85 percent. The efficiency after cooling the cathode increased from 53 to 67 percent.

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.

Having thus described my invention, what I claim is:

1. A device for stabilizing the current in an electron beam generated from a cathode to an anode located in a chamber which is evacuated to a predetermined pressure level necessary for operating the cathode with a glow discharge comprising:
   a cathode structure,
   power supply means for negatively charging said cathode structure with respect to the anode for producing said glow discharge and the beam of electrons from said cathode,
   a source of cooling fluid,
   a cooling conduit in heat conducting relationship with said cathode structure,
   means including a valve for interconnecting said conduit with the source of cooling fluid, said valve regulating the flow rate of said coolant through the conduit,
   means for scheduling a signal indicative of the desired current from the anode to the cathode,
   means for sensing the actual current between the cathode and the anode and producing a signal indicative thereof,
   means comparing the sensed current signal with the scheduled current signal for producing an error signal indicative of the deviation of the current from the desired value,
   means responsive to the error signal and coupled to the valve for varying the rate of coolant flow in a direction tending to drive said error to a minimum value.

2. A device as recited in claim 1 wherein said scheduling means comprises:
a trim control actuated by the desired current signal and producing a second desired current value signal, and wherein said second desired current value signal is coupled to the comparing means for comparison with the actual current signal.

3. A device as recited in claim 2 wherein said trim control comprises:
a variable resistor having a wiper arm, means applying a voltage across said variable resistor, means responsive to the first desired current signal for selectively varying the position of the wiper arm, with said wiper arm being electrically coupled to the comparison means.

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