NASA TECHNICAL MEMORANDUM

NASA TM X-52926

COMPUTER-ACQUIRED PERFORMANCE MAP OF AN ETCHED-RHENIUM, NIOBIUM PLANAR DIODE

by Richard B. Lancashire
Lewis Research Center
Cleveland, Ohio

TECHNICAL PAPER proposed for presentation at
1970 Thermionic Conversion Specialists Conference sponsored by
the Institute of Electrical and Electronics Engineers
Miami, Florida, October 26-29, 1970

COMPUTER-ACQUIRED PERFORMANCE MAP OF
AN ETCHED-RHENIUM, NIOBIUM PLANAR DIODE

Richard B. Lancashire
NASA-Lewis Research Center
Cleveland, Ohio 44135

Abstract

A fixed-spaced planar diode with a guarded collector has been performance-mapped in a multi-station facility which is connected to a centralized computer data acquisition system. The etched-rhenium emitter was separated from the niobium collector by 10 mils. The use of the computer system allowed off-design as well as on-design conditions to be observed. Emitter temperatures from 1550° K to 2050° K were tested. Collector temperatures were varied from 750° to 1180° K, and cesium reservoir temperatures were varied from 525° K to 650° K. The data are presented on J,V and P,V plots. The collection of the many current, voltage curves was achieved by sweeping the diodes over a period of approximately 10 milliseconds with a variable electronic load controlled by the central digital computer.

E-6017

Introduction

Lower operating temperatures associated with out-of-core thermionics allow the use of electrode materials prohibited by in-core operations. With this fact in mind, plus having available a computerized data acquisition system as described by Breitwieser et al. in reference 1, a program has been initiated to map the performance at off-design as well as on-design conditions of various electrode combinations. Part of this program are six converters built on contract by the Thermo Electron Corporation. Niobium and molybdenum are the collector materials in these diodes, and rhenium and tungsten, in various forms of surface preparation are the emitter materials. The first of these combinations, reported herein, has an etched rhenium emitter separated by 10 mils from a guarded niobium collector. The converter is described by Speidel and Williams in reference 2.

Selected data are presented in current density, voltage (J,V) and power density, voltage (P,V) plots. Data was gathered for emitter temperatures from 1550° K to 2050° K. The collector was varied from 750° K to 1180° K, and the cesium reservoir from 525° K to 650° K.

Test Facility

Vacuum Stations

Individual diodes (Figure 1) are mounted in any of six vacuum test stations which, through patch boards, are connected directly "on line" to the computer data acquisition system (1). Each station has its own set of electron-bombardment, collector, and cesium-reservoir heater supplies. Thermal balance of the collector and reservoir is achieved through conduction to water lines.

Instrumentation

The current developed in the converter was measured by the voltage drop across either a 0.01- or 0.1-ohm precision shunt. The variable transistorized load across the diode was pulsed using a triangular waveform with a period of approximately 10 milliseconds. The computer data acquisition system (1), synchronized with this pulse, made 180 different data readings during the pulse. Sample-and-hold amplifiers were used to coordinate, in time, every three of these readings. Two of every three data observations were currents; one was amplified ten times greater than the other. The third reading was the voltage developed between the emitter and collector. Thus during a period of approximately 10 milliseconds, 60 synchronized current, voltage data points were obtained. The voltages were measured at the external shroud of the converter, and no corrections were made for shroud losses, since it is estimated that the effective resistance of the shroud is only 1.8 mv/amp/cm^2. The area used in determining the current density was that of the collector, 1.55cm^2. The guard ring was electrically connected to the circuit on the opposite side of the shunt from the collector.

The emitter temperature was measured by observing the total gray-body radiation emitted by the edge of the emitter as viewed through a window in the vacuum chamber (Figure 1). A fast-response photomultiplier was used for this measurement and was calibrated in situ using an optical pyrometer sighted on a black body cavity in the edge of the emitter. The pyrometer and window were calibrated using a NBS lamp. It is estimated that the maximum error associated with all the observed emitter temperatures is approximately ±10 to 12° K.

The observed emitter temperature was corrected for the gradient through the emitter to the active surface. This correction, which varied from 5 to 18° K, was based on a one-dimensional model equating the thermal radiation across the interelectrode gap to the heat conducted through the emitter.

The collector and cesium reservoir temperatures were observed using Chromel, Alumel thermocouples embedded in the converter. Two couples were inserted at each location. The reservoir couples were set in a copper block surrounding the reservoir tube (Figure 1). Their readings varied 2 to 3° K and their average values are shown on the data curves.

All temperatures were recorded by the computer at the end of each pulse.

Test Procedure

The converter performance was mapped by fixing a cesium reservoir temperature and a collector temperature, and ramping the emitter temperature, either upwards or downwards, by changing the input power to the emitter. Ten different emitter temperatures between 1550° K and 2050° K at approximately 50° K increments were observed in this manner. The collector temperature was then changed, and the procedure was repeated. Five different collector temperatures between 750° K and 1180° K at approximately 100° K increments were observed. The cesium reservoir was

Presented at the 1970 Thermionic Conversion Specialists Conference, October 26 through 29, 1970, Miami, Florida

X-52926

then changed, and the procedure was again repeated. Six different reservoir temperatures between 525° K and 650° K at 25° K increments were established.

At least one sweep or pulse of the variable electronic load was made at each one of the reservoir, collector, and emitter-temperature conditions. Approximately 350 sweeps are necessary to map a fixed-space converter.

Data Presentation

Since the local computer can store and recall only a limited number of successive sweeps, the data are transmitted to the Lewis Central Computing Center for storage on magnetic tape and engineering calculations. This stored information is then edited, either by visually scanning the 35 mm output from the Central Computer or allowing the computer to sort the data into discreet parametric groups. Approximately half of the total number of sweeps represent unique conditions. Examples of the direct J,V output are shown on Figures 2a, 3a, and 4a. Figures 2b, 3b, and 4b are P,V curves generated by the Central computer from the J,V data. Emitter temperatures represented on these curves are 1700, 1800, and 1900° K. The collector temperatures are approximately 950° K and the cesium reservoir temperature is approximately 650° K. The square symbols indicate a change in voltage from right to left, and the round symbols indicate left to right voltage change.

After sorting the data into groups of common emitter temperatures, the J,V points for one T_e and varying T_c and T_r are plotted on a single graph by the computer. The envelope of these points represents near-optimum performance of the converter at the particular T_e. Figures 5 through 7 are examples of this procedure. They cover emitter temperatures from 1700° ±10° K to 1900°±10° K. Similar envelopes are obtained at all other T_e's. The definition of the envelope curves generated in this fashion is, of course, a function of the number of J,V sweeps obtained at optimized collector temperatures. Since this method of data display does not yield the actual value of the optimum collector temperature, the computer sorts the data further into groups of common collector temperatures and again plots all data on a single graph. An example of this procedure is shown on Figure 8. By comparing curves at different collector temperatures, one can pinpoint the optimum collector temperature at a given T_e. Figure 9 shows all of the performance envelopes for the converter as obtained by the massive plotting of data. It appears that the ignited portion of these curves can be represented by straight lines with very nearly common slopes.

The performance of this planar converter is compared to a cylindrical converter of the same electrode combination on Figure 10. The maximum electrode efficiency is plotted against emitter temperature on this figure. The cylindrical-diode data obtained by Kascak and Williams (ref. 3) are used. Their efficiencies were calorimetrically measured, whereas the present values have been calculated using the envelope J,V curves at various T_e's. This calculation is based on electron cooling from the emitter, and thermal radiation and gaseous conduction across the interelectrode gap. Back emission was neglected. The error bars on the calculated values indicate the uncertainty of the simplified calculation and in particular, the effective emittance of the rhenium, niobium combination. This emittance uncertainty was discussed by Williams and Bifano in reference 4.

Concluding Remarks

Performance data from an etched-rhenium, niobium converter have been presented. These data were gathered using a computer system which allowed off-design as well as on-design conditions to be observed over a relatively short period of operation. Furthermore, it has been shown that the computer system can display the data in an immediately usable form.

References

1. R. Breitwieser, E. J. Manista, and A. L. Smith, "Computerized Performance Mapping of a Thermionic Converter with Oriented Tungsten Electrodes." IEEE Thermionic Specialist Conference, Carmel, October 1969.

2. T. O. Speidel and R. M. Williams, "Fixed-Space Planar Thermionic Diode with Collector Guard Ring." IEEE Thermionic Specialist Conference, Framingham, Mass., October 1968.

3. T. Kascak and R. M. Williams, "The Performance of a Rhenium, Niobium Cylindrical Converter." IEEE Thermionic Specialist Conference, Framingham, October 1968.

4. R. M. Williams and W. J. Bifano, "Thermal Performance of Rhenium-Niobium Cylindrical Thermionic Converter." NASA TN D-4582, 1968.

CONVERTER CONFIGURATION

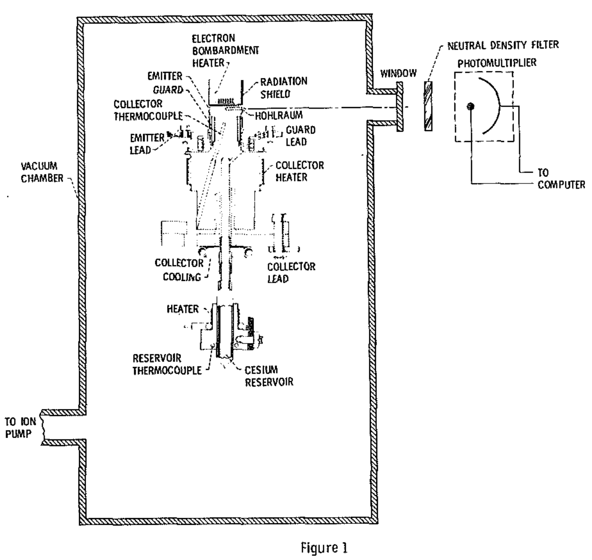

Figure 1

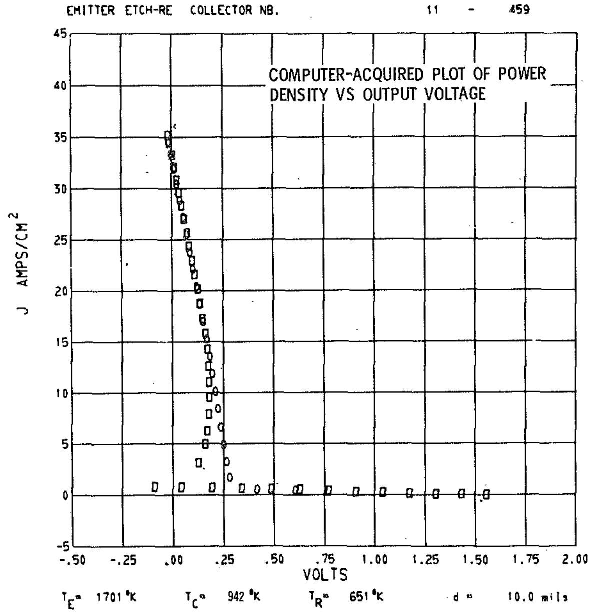

Figure 2(a)

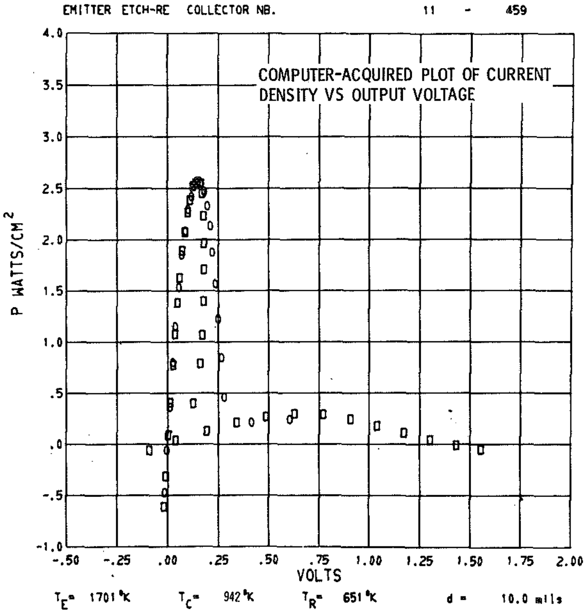

Figure 2(b)

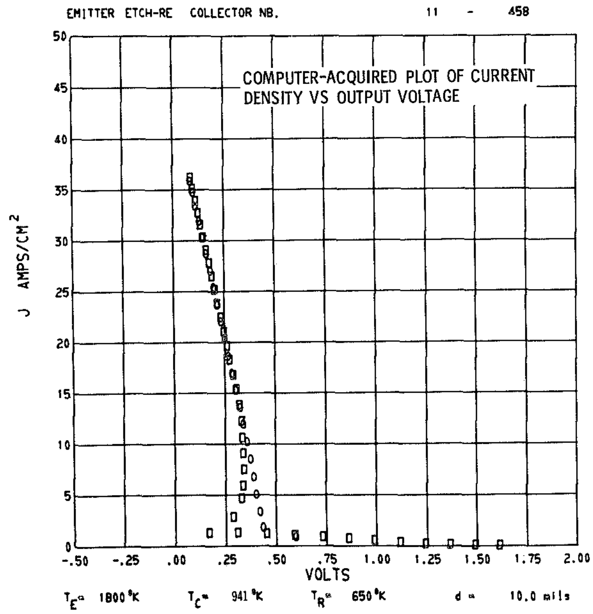

Figure 3(a)

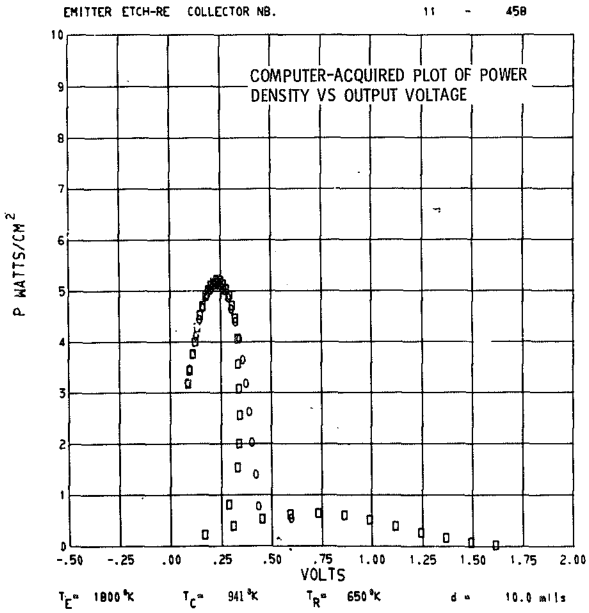

Figure 3(b)

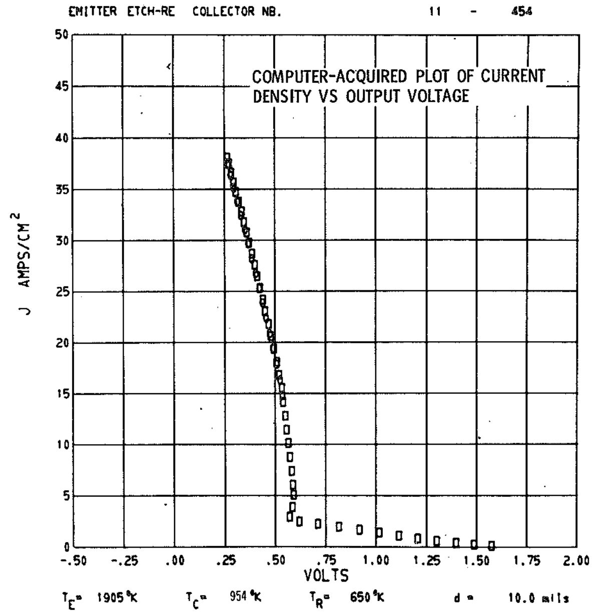

Figure 4(a)

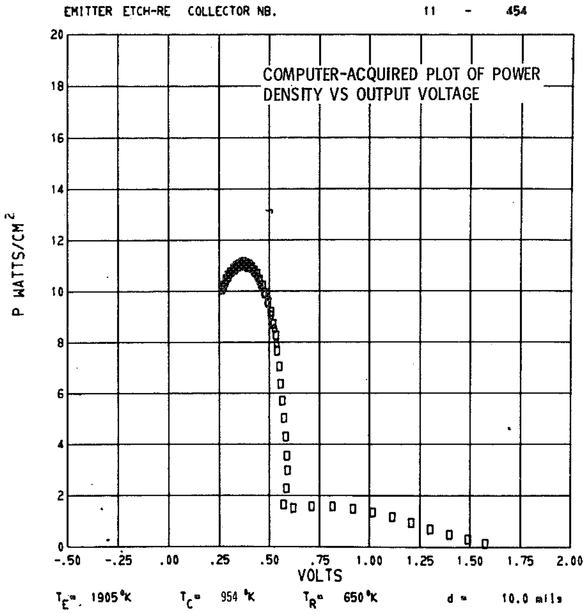

Figure 4(b)

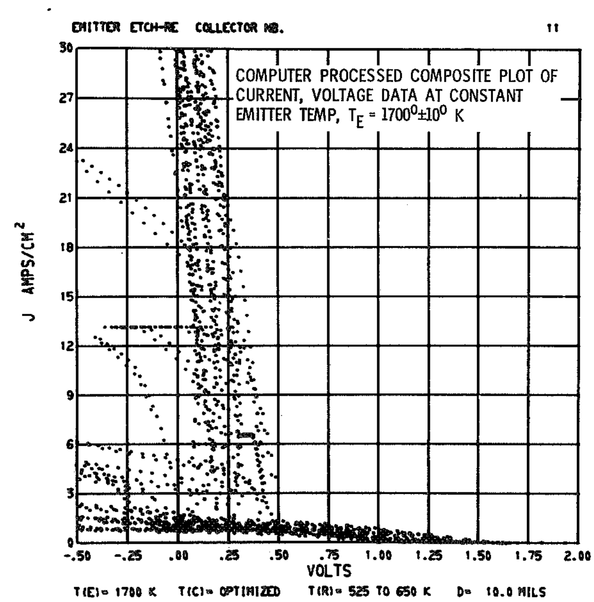

Figure 5

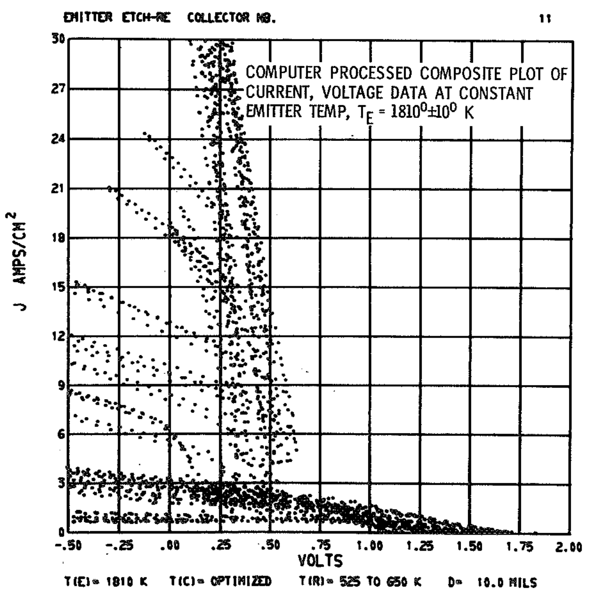

Figure 6

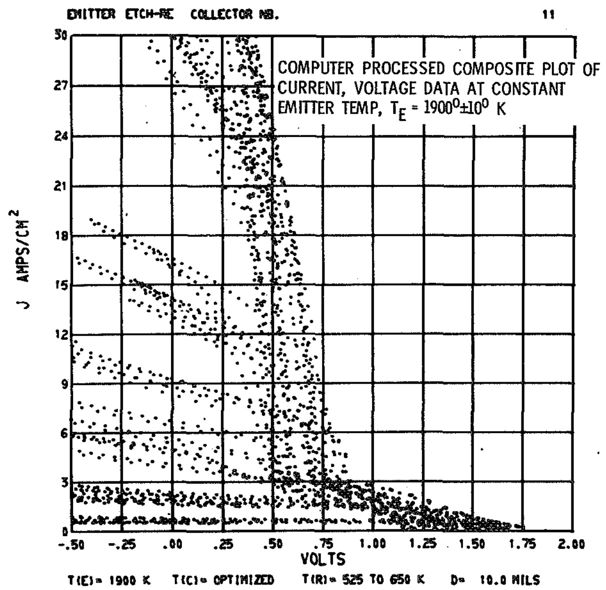

Figure 7

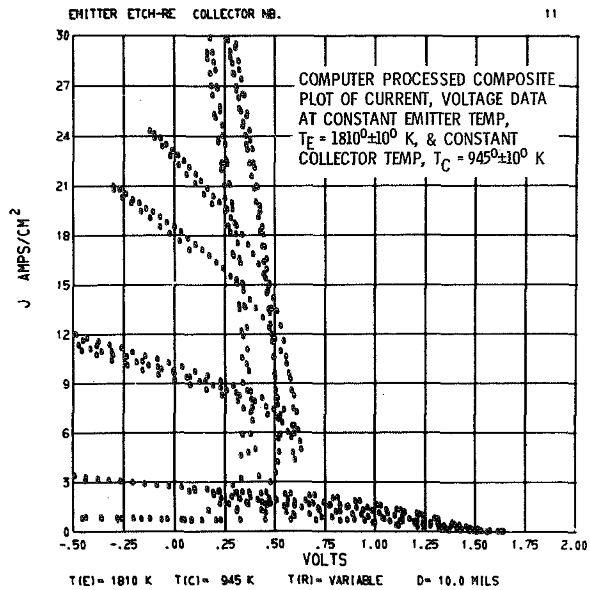

Figure 8

PERFORMANCE ENVELOPES FOR ETCHED-RHENIUM, NIOBIUM PLANAR CONVERTER AT VARIOUS EMITTER TEMPERATURES

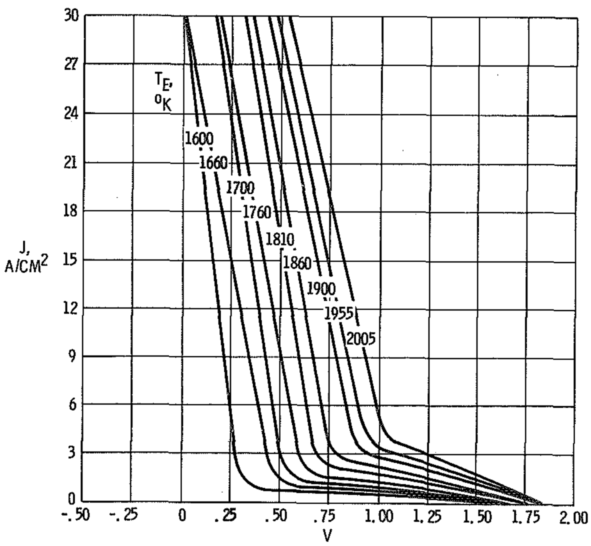

Figure 9

MAXIMUM ELECTRODE EFFICIENCY OF PLANAR AND CYLINDRICAL CONVERTERS

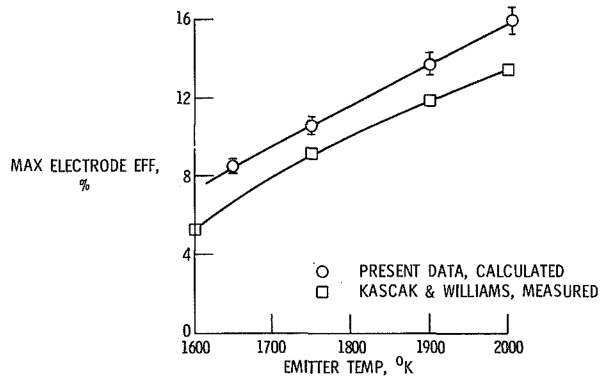

Figure 10

NASA-Lewis