N72-14028

NASA TECHNICAL MEMORANDUM

NASA TM X-2481

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COMPUTER-ACQUIRED PERFORMANCE DATA FROM AN ETCHED-RHENIUM, MOLYBDENUM PLANAR DIODE

by Eugene J. Manista

Lewis Research Center

Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JANUARY 1972

1. Report No. NASA TM X-2481	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
COMPUTER-ACQUIRED PERFORMANCE DATA FROM AN ETCHED-RHENIUM, MOLYBDENUM PLANAR DIODE

5. Report Date
January 1972

6. Performing Organization Code

7. Author(s)
Eugene J. Manista

8. Performing Organization Report No.
E-6610

10. Work Unit No.
112-27

9. Performing Organization Name and Address
Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio 44135

11. Contract or Grant No.

13. Type of Report and Period Covered
Technical Memorandum

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
Performance data from an etched-rhenium, molybdenum thermionic converter are presented. The planar converter has a guard-ringed collector and a fixed spacing of 0.254 mm (10 mils). The data were acquired by using a computer and are available on microfiche as individual or composite parametric current, voltage curves. The parameters are the temperatures of the emitter T_E, collector T_C, and cesium reservoir T_R. The composite plots have constant T_E, and varying T_C or T_R, or both. The envelope and composite plots having constant T_E are presented. The diode was tested at increments between 1500 and 2000 K for the emitter, 750 and 1100 K for the collector, and 540 and 640 K for the reservoir. In all, 774 individual current, voltage curves were obtained.

17. Key Words (Suggested by Author(s))
Thermionic energy convertor
Computer data acquisition

18. Distribution Statement
Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	15	$3.00

* For sale by the National Technical Information Service, Springfield, Virginia 22151

COMPUTER-ACQUIRED PERFORMANCE DATA FROM AN ETCHED-RHENIUM, MOLYBDENUM PLANAR DIODE

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SUMMARY

A fixed-space planar diode with a guarded collector has been performance mapped in a multistation facility which is connected to a centralized computer data acquisition system. The etched-rhenium emitter was separated from the molybdenum collector 0.254 millimeter (10 mils). The use of the computer system allowed off-design as well as optimum conditions to be observed. Temperatures ranged from 1500 to 2000 K for the emitter (T_E), 750 to 1100 K for the collector (T_C), and 540 to 640 K for the cesium reservoir (T_R). The composite plots and their envelopes, with constant T_E and varying T_C and T_R, are presented. Each of the 774 current, voltage curves was obtained in approximately 10 milliseconds with a variable transistorized load controlled by the central digital computer.

INTRODUCTION

More power at lower temperatures is the goal for nuclear thermionic diodes. Providing that improvement means intensive testing of the best existing emitters and collectors, promising new electrodes, and additives. To ensure success, performance mapping must cover off-design as well as optimum operating conditions - with special attention to stability problems. Part of this program is the evaluation of six planar diodes with guarded collectors of niobium or molybdenum spaced a quarter of a millimeter from emitters of rhenium or tungsten (ref. 1). The results obtained for the electrode combination of an etched-rhenium emitter and a molybdenum collector are presented in this report. Similar results for emitters of physically vapor-deposited tungsten, chemically vapor-deposited tungsten, and etched rhenium with niobium collectors are presented in references 2 to 5.

Data were recorded by using a computer system as described in reference 6. This facility allows the rapid application of a variable transistorized load and makes possible the testing at off-design as well as optimum conditions. The data are presented on composite J, V plots holding the emitter temperature T_E constant and varying the collector and cesium reservoir temperatures T_C and T_R. Data were gathered between 1500 and 2000 K for the emitter, 750 and 1100 K for the collector, and 540 to 640 K for the reservoir.

TEST FACILITY

Test Stations

The converters (fig. 1) were fabricated and then filled with cesium by the contractor.[1] They may be mounted in any of six vacuum test stations which have a central instrumentation control panel. Each station has its own set of emitter (electron-bombardment), collector, and cesium-reservoir heat supplies. Thermal balance of the collector and reservoir is achieved through conduction to water lines. Typical operating pressures under heat load for these systems are less than 5×10^{7} torr after a thorough bake-out.

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 emitter, collector potential difference was measured at the external shroud of the converter. No corrections were made for the voltage drop in the emitter support shroud since it is approximately 1.8 millivolts per ampere per square centimeter of electrode surface. The current density was determined for the 1.55-square-centimeter collector. The guard ring was connected to the circuit on the opposite side of the shunt from the collector.

The collector and cesium-reservoir temperatures were observed by using sheathed Chromel, Alumel thermocouples embedded in their respective converter structures. The thermocouples were continuous and were brought through the vacuum wall of the test station into a common ambient cold junction zone. The temperature of the ambient zone was sensed by a Chromel, Alumel thermocouple that was referenced electronically to 273 K. Two thermocouples were inserted at each location. The cesium-reservoir thermocouples were located in the copper block surrounding the copper tube containing

[1]Thermo Electron Engineering Crop., Waltham, Mass.

the cesium (fig. 1). The collector thermocouples were inserted to within 3.05 millimeters (125 mils) of the collector surface. The Chromel, Alumel standard calibration for all four thermocouples was verified by an in situ comparison against a Chromel, Alumel reference thermocouple.

The emitter temperature was sensed by a sheathed high-temperature tungsten, 5-percent-rhenium/tungsten, 26-percent-rhenium thermocouple. The thermocouple was inserted to a depth of 6.34 millimeters (250 mils) from the emitter substrate edge and 3.3 millimeters (130 mils) from the active face of the emitter (see fig. 1). Compensating lead wires were attached to the thermocouple on the interior of the test chamber and were brought out to a room-temperature junction. The high-temperature thermocouple was calibrated in place against a black-body cavity (length-to-diameter ratio of 5) in the emitter in the same plane of the thermocouple. Observations of the black-body cavity were made through a window in the test station with an automatic disappearing filament optical pyrometer. The optical path and pyrometer were calibrated against a National Bureau of Standards (NBS) tungsten strip lamp. The maximum uncertainty associated with the observed temperature is approximately ±10 K. This estimate takes into account the accuracy of the NBS calibration, the reversal capabilities of the optical pyrometer, and the effect of the approximately black-body cavity. The temperature difference between the emitter thermocouple location and the active face of the emitter is considered negligible based on a one-dimensional heat balance of the radiation across the interelectrode gap and the heat conducted through the emitter. This model neglects any heat flow through the emitter-support shroud since the electron-bombardment filament was designed to nullify this heat path. Electron cooling effects on the surface temperature are negligible since the time interval over which the load is applied is very short and the converter is held at a low-current, retarded-voltage condition between tests (ref. 6). The contribution of gaseous conduction is negligible.

TEST PROCEDURE

The computer-controlled data acquisition system is programmed to trigger the variable load at up to six different emitter temperatures during a given test interval, which is usually approximately 20 seconds. (The program was developed by E. J. Manista and C. T. Kadow of the Lewis Research Center.) This is accomplished by sensing the emitter temperature and, upon its reaching a predetermined value, triggering the load. The actual temperature levels at which the system is triggered are introduced into the program by the operator as independent input data. The data recording program, synchronized with the variable load, samples the J, V characteristic of the converter at 90 points during the load application of approximately 10-millisecond duration. Sample and hold amplifiers coordinate in time the collector current and collector, emitter potential difference.

The converter was mapped by fixing the temperatures of the cesium reservoir and the collector and heating the emitter to the predetermined levels. By changing the programmed trigger levels, the emitter was tested at 50 K increments between 1500 and 2000 K. The collector temperature was then changed, and the preceding procedure was repeated. Observations were made at 50 K collector increments between 750 and 1100 K. The cesium reservoir temperature was then changed, and the procedure was again repeated. Eight reservoir temperatures between 540 and 640 K were established. At least one pulse of the variable transistorized load was made at each one of the reservoir-, collector-, emitter-temperature combinations. All temperatures were recorded at the end of each J, V sweep. Between sweeps, these analog temperatures were converted by the computer to their values in Kelvin, and then printed out for use by the operator in setting conditions.

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 for some engineering calculations. The data are sorted into groups of common emitter temperatures and are displayed in order of ascending T_E on microfilm output. Both J, V and P, V (power density, voltage) curves are displayed, with the J and P scales being determined by the maximum of each sweep. Two additional sorts are done by the central computer: the data are grouped by common emitter and collector temperatures and by common emitter and reservoir temperatures. The computer plots all sorted J, V data on parametric composites and displays them on the microfilm output. These have scales of -0.5 to 2 volts and 0 to 30 amperes per square centimeter.

Table I lists the temperature conditions for the composite plots presented in figures 2 to 12. These figures show all J, V data obtained at emitter temperatures from 1500 to 2000 K. The envelope of the points of these figures represents the optimum performance of the converter for the range of operating conditions. All envelopes for the different T_E's appear in figure 13. Although the last figure yields all information contained in figures 2 to 12, the individual computer-processed plots are presented to illustrate the density of data required to adequately establish the optimum envelope curves.

In all, 774 individual J, V plots were generated in developing these envelopes. These are available in microfiche form on request from the author. Also available on microfiche are J, V composites at constant T_E and constant T_C or T_R. Table II lists the temperature conditions included on these computer-processed plots.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, November 1, 1971,
112-27.

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TABLE I. - TEMPERATURE CONDITIONS FOR

COMPOSITE PLOTS (FIGS. 2 TO 12)

Figure	Emitter temperature, T_E, K	Collector temperature, T_C, K	Cesium-reservoir temperature, T_R, K	Number of current, voltage curves
2	1500	749 to 1100	538 to 642	64
3	1550	749 to 1104	538 to 642	
4	1600	750 to 1106	539 to 643	
5	1650	750 to 1107	538 to 643	
6	1700	751 to 1108	538 to 642	
7	1750	751 to 1109	538 to 643	
8	1800	747 to 1106	539 to 641	
9	1850	747 to 1108	540 to 641	
10	1900	748 to 1109	540 to 642	
11	1950	748 to 1110	540 to 641	
12	2000	750 to 1112	539 to 641	

TABLE II. - TEMPERATURE CONDITIONS FOR COMPUTER-PROCESSED PLOTS

Emitter temperature, T_E, K	Collector temperature, T_C, K	Cesium-reservoir temperature, T_R, K	Emitter temperature, T_E, K	Collector temperature, T_C, K	Cesium-reservoir temperature, T_R, K	Emitter temperature, T_E, K	Collector temperature, T_C, K	Cesium-reservoir temperature, T_R, K
1500	750	538 to 641	1700	750	538 to 641	1900	750	542 to 640
	800	539 to 641		800	540 to 641		800	541 to 641
	850	539 to 639		850	539 to 639		850	542 to 642
	900	540 to 640		900	541 to 640		900	543 to 641
	950	542 to 641		950	542 to 641		950	543 to 642
	1000	542 to 642		1000	542 to 642		1000	540 to 641
	1050	542 to 642		1050	542 to 642		1050	541 to 639
	1100	542 to 642		1100	542 to 642		1100	542 to 639
1550	750	538 to 641	1750	750	538 to 641	1950	750	542 to 639
	800	540 to 642		800	540 to 641		800	541 to 640
	850	539 to 640		850	539 to 639		850	542 to 641
	900	540 to 640		900	541 to 641		900	543 to 640
	950	542 to 641		950	542 to 641		950	543 to 641
	1000	541 to 642		1000	541 to 642		1000	540 to 640
	1050	543 to 642		1050	542 to 643		1050	541 to 639
	1100	541 to 642		1100	542 to 642		1100	542 to 639
1600	750	539 to 641	1800	750	542 to 639	2000	750	542 to 639
	800	540 to 642		800	541 to 640		800	541 to 640
	850	539 to 640		850	542 to 641		850	542 to 641
	900	541 to 641		900	542 to 640		900	542 to 640
	950	542 to 641		950	543 to 641		950	543 to 641
	1000	542 to 642		1000	539 to 640		1000	539 to 640
	1050	543 to 643		1050	541 to 639		1050	541 to 640
	1100	542 to 642		1100	542 to 639		1100	542 to 639
1650	750	538 to 641	1850	750	542 to 639			
	800	540 to 641		800	541 to 640			
	850	539 to 640		850	542 to 641			
	900	541 to 640		900	542 to 640			
	950	542 to 642		950	543 to 641			
	1000	542 to 642		1000	540 to 640			
	1050	543 to 643		1050	541 to 639			
	1100	542 to 642		1100	542 to 639			

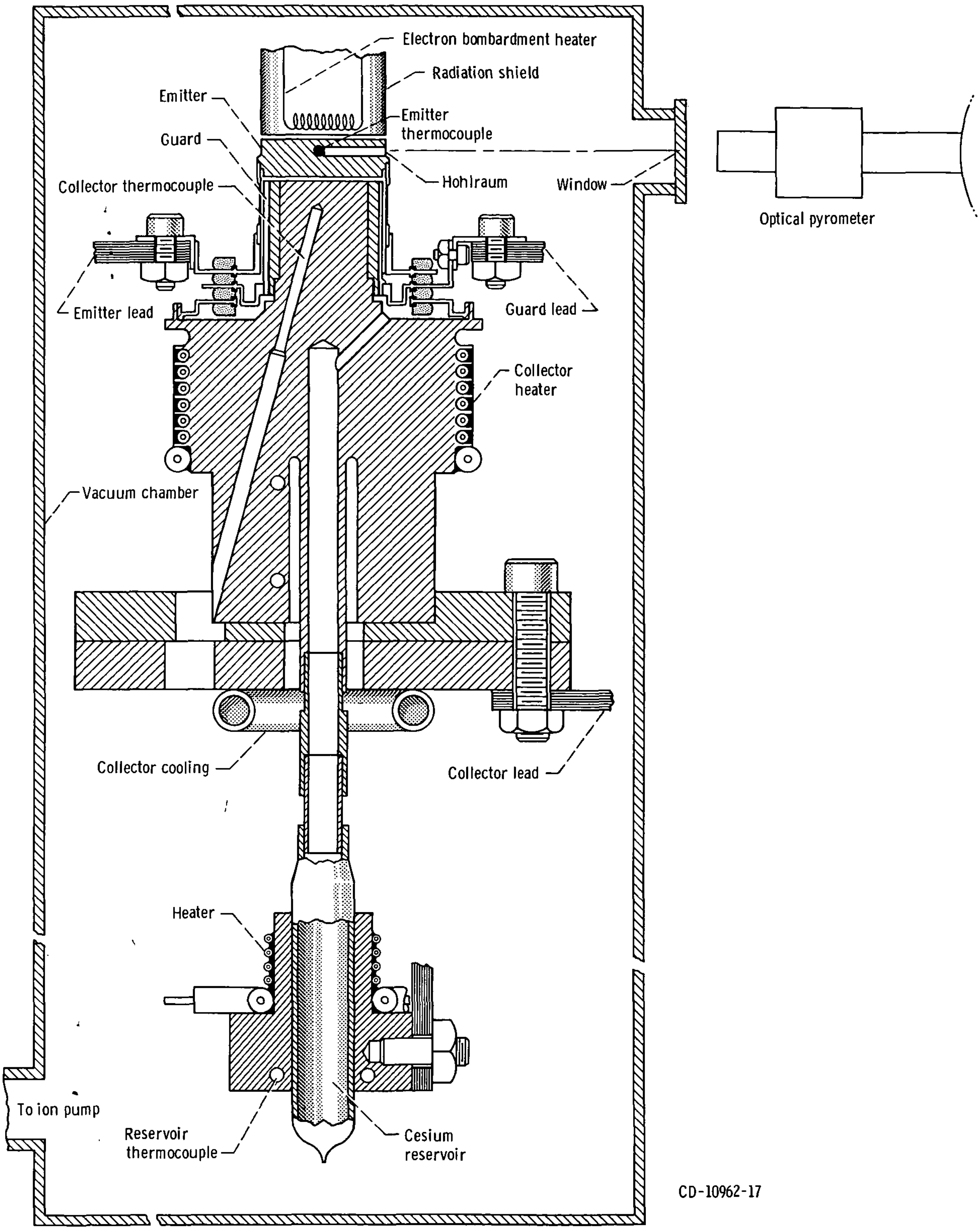

Figure 1. - Converter configuration.

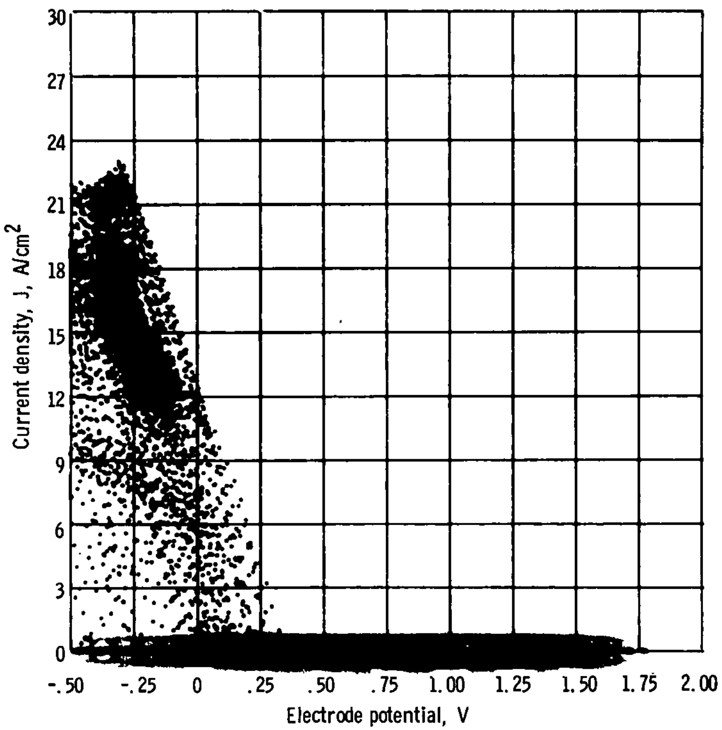

Figure 2. - Computer-processed composite of current, voltage data at constant emitter temperature of 1500 K. Collector temperature, 749 to 1100 K; cesium-reservoir temperature, 538 to 642 K; interelectrode space, 0.254 millimeter (10 mils).

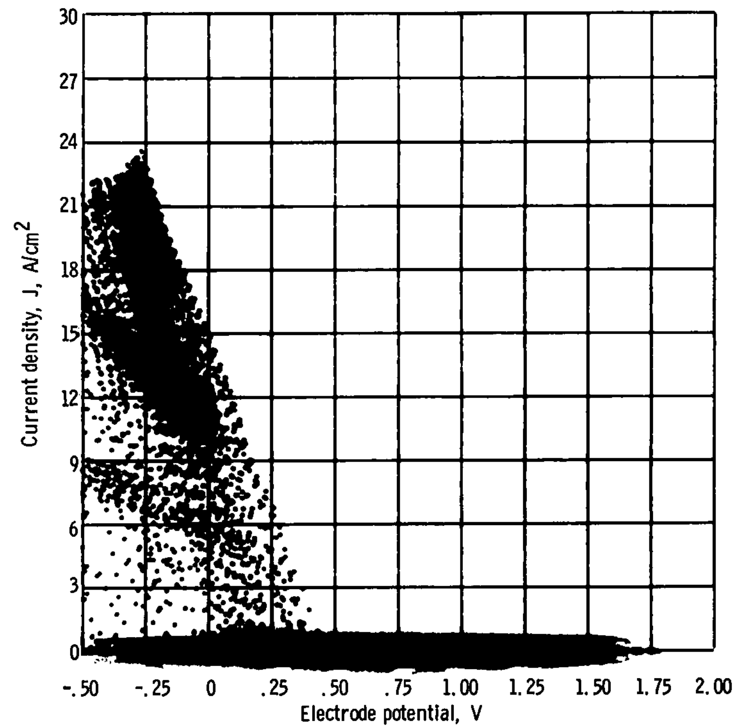

Figure 3. - Computer-processed composite of current, voltage data at constant emitter temperature of 1550 K. Collector temperature, 749 to 1104 K; cesium-reservoir temperature, 538 to 642 K; interelectrode space, 0.254 millimeter (10 mils).

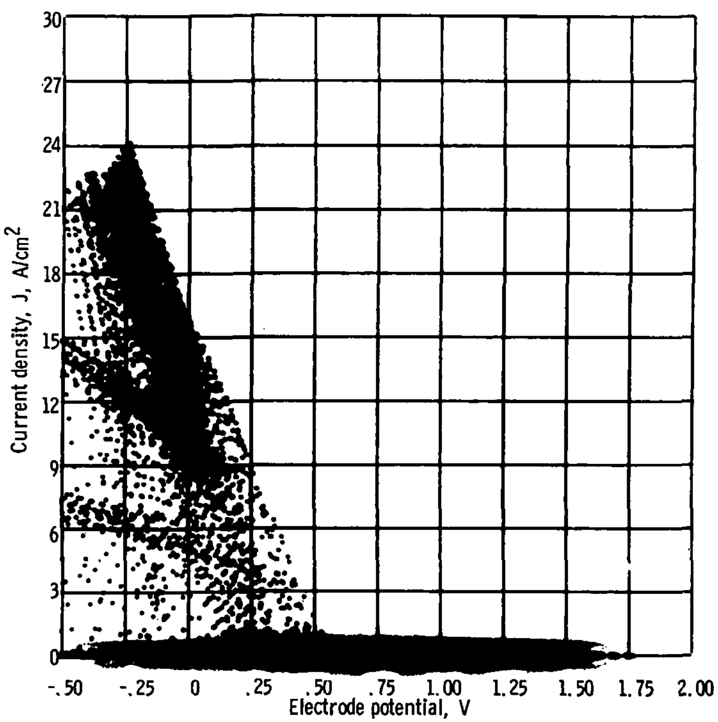

Figure 4. - Computer-processed composite of current, voltage data at constant emitter temperature of 1600 K. Collector temperature, 750 to 1106 K; cesium-reservoir temperature, 539 to 643 K; interelectrode space, 0.254 millimeter (10 mils).

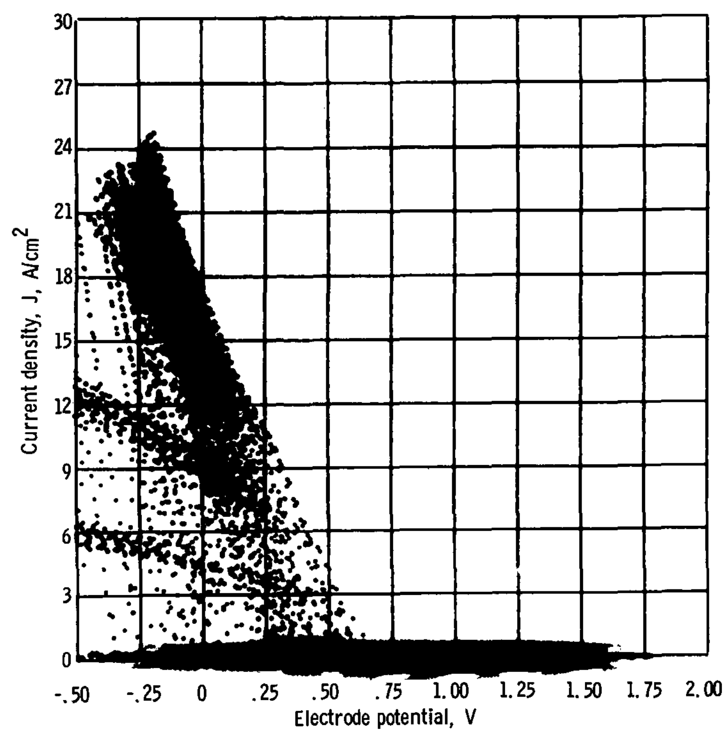

Figure 5. - Computer-processed composite of current, voltage data at constant emitter temperature of 1650 K. Collector temperature, 750 to 1107 K; cesium-reservoir temperature, 538 to 643 K; interelectrode space, 0.254 millimeter (10 mils).

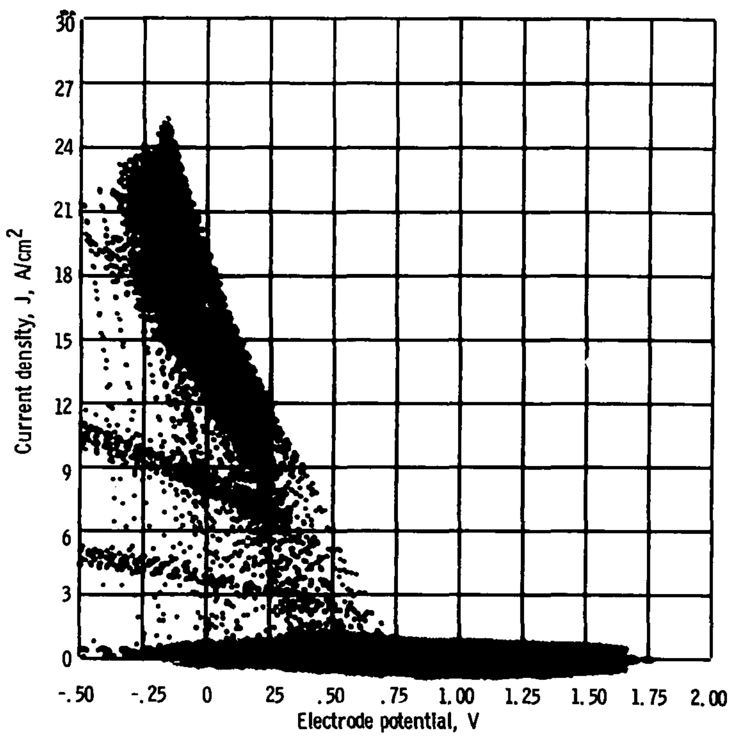

Figure 6. - Computer-processed composite of current, voltage data at constant emitter temperature of 1700 K. Collector temperature, 751 to 1108 K; cesium-reservoir temperature, 538 to 642 K; interelectrode space, 0.254 millimeter (10 mils).

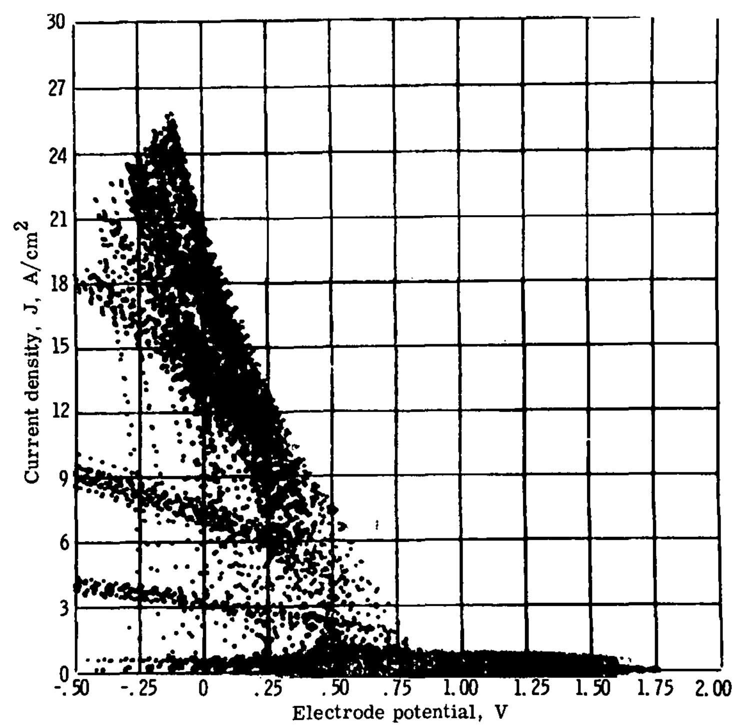

Figure 7. - Computer-processed composite of current, voltage data at constant emitter temperature of 1750 K. Collector temperature, 751 to 1109 K; cesium-reservoir temperature, 538 to 643 K; interelectrode space, 0.254 millimeter (10 mils).

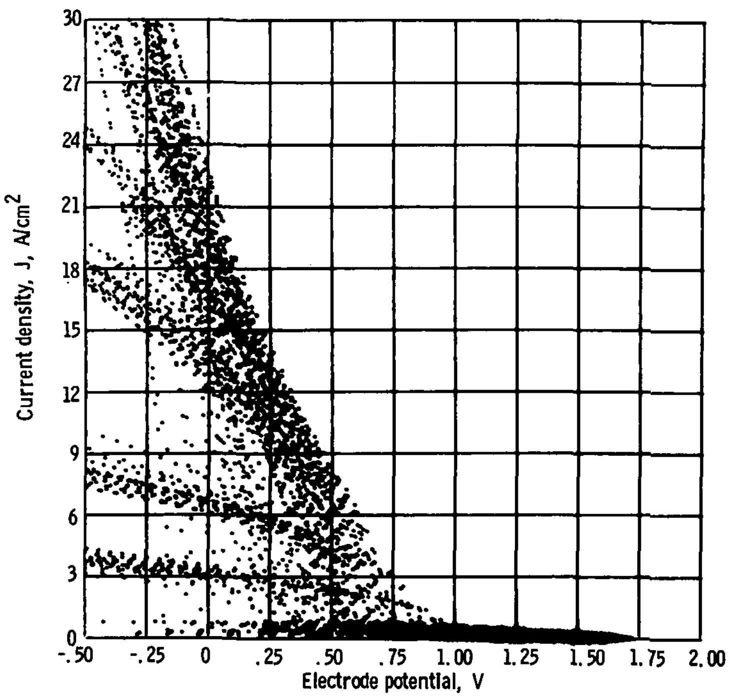

Figure 8. - Computer-processed composite of current, voltage data at constant emitter temperature of 1800 K. Collector temperature, 747 to 1106 K; cesium-reservoir temperature, 539 to 641 K; interelectrode space, 0.254 millimeter (10 mils).

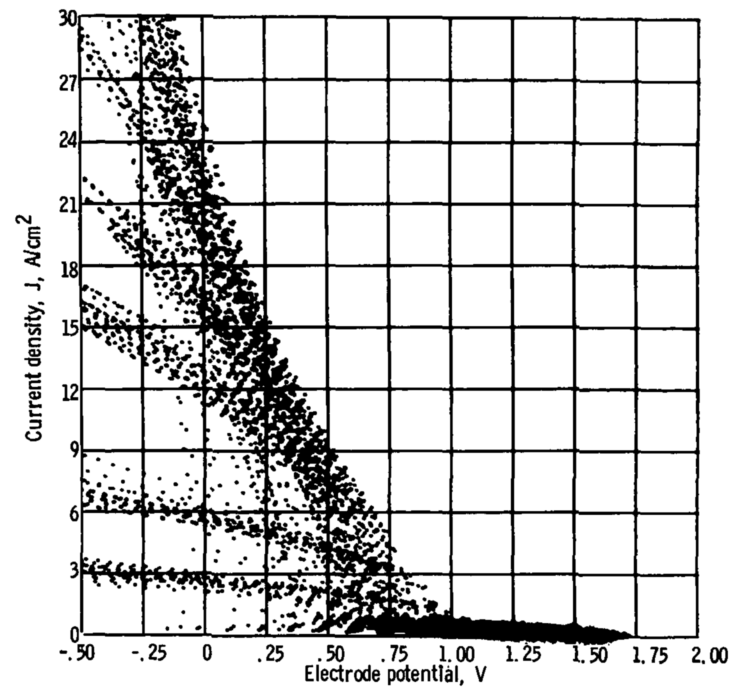

Figure 9. - Computer-processed composite of current, voltage data at constant *emitter temperature of 1850 K. Collector temperature, 747 to 1108 K*; cesium-reservoir temperature, 540 to 641 K; interelectrode space, 0.254 millimeter (10 mils).

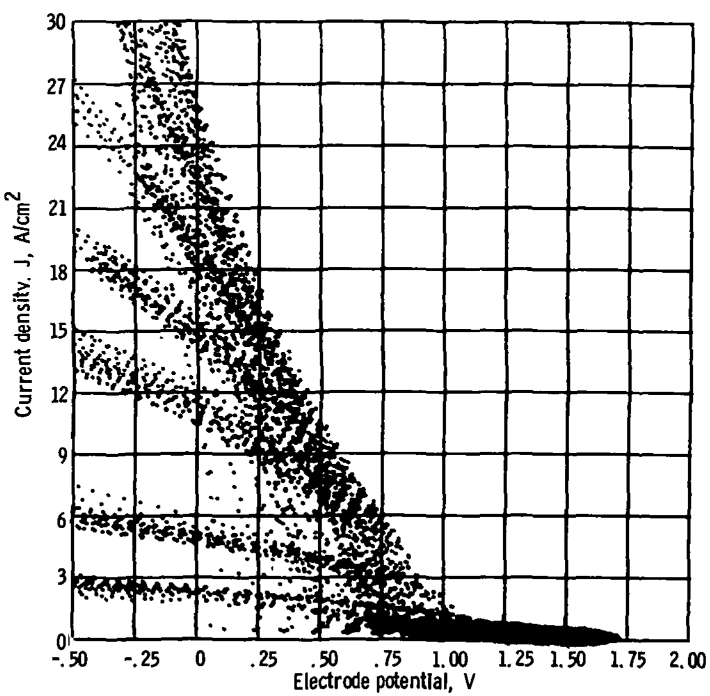

Figure 10. - Computer-processed composite of current, voltage data at constant emitter temperature of 1900 K. Collector temperature, 748 to 1109 K; cesium-reservoir temperature, 540 to 642 K; interelectrode space, 0.254 millimeter (10 mils).

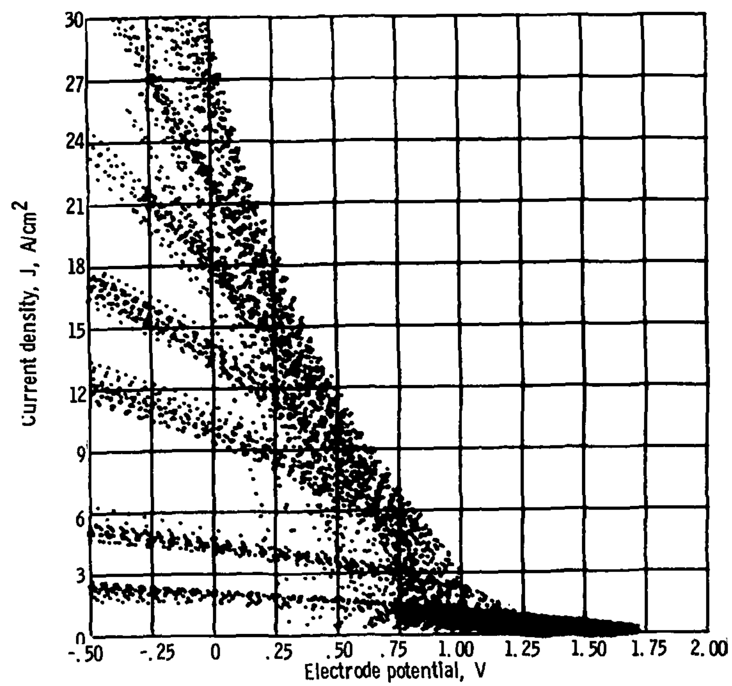

Figure 11. - Computer-processed composite of current, voltage data at constant emitter temperature of 1950 K. Collector temperature, 748 to 1110 K; cesium-reservoir temperature, 540 to 641 K; interelectrode space, 0.254 millimeter (10 mils).

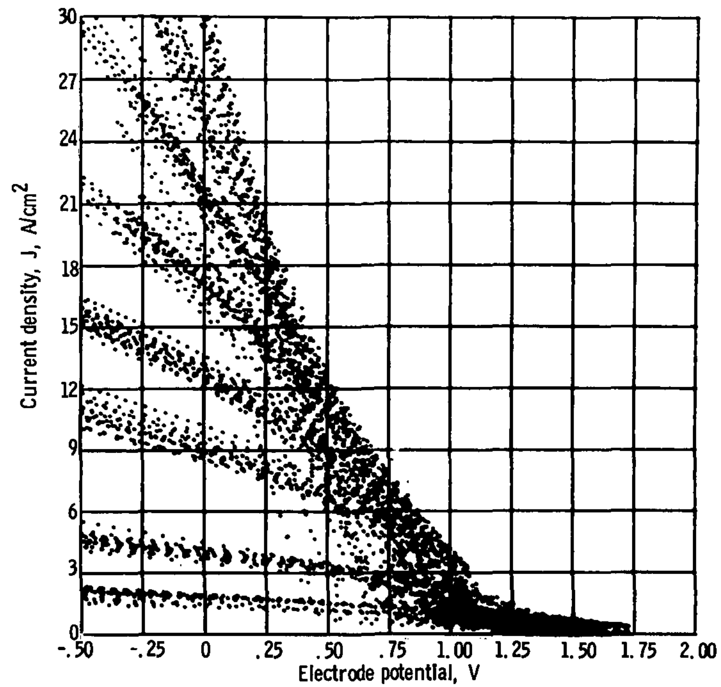

Figure 12. - Computer-processed composite of current, voltage data at constant emitter temperature of 2000 K. Collector temperature, 750 to 1112 K; cesium-reservoir temperature, 539 to 641 K; interelectrode space, 0.254 millimeter (10 mils).

NASA-Langley, 1972 —— 3 E-6610

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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