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DIMINIODE PERFORMANCE DATA WITH AN ASTAR-811C EMITTER AND A NIOBIUM - 1-PERCENT-ZIRCONIUM COLLECTOR

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16. Abstract

The performance of a fixed-space planar miniature diode (diminiode) with a guarded collector has been mapped using a computerized data-acquisition facility. The electrode materials consisted of a tantalum alloy (ASTAR-811C) emitter and a Nb-1Zr collector; the electrode gap was 0.254 mm.

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DIMINIODE PERFORMANCE DATA WITH AN ASTAR-811C EMITTER AND A NIOBIUM - 1-PERCENT-ZIRCONIUM COLLECTOR

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SUMMARY

The performance of a fixed-space planar miniature diode (diminiode) with a guarded collector has been mapped using a computerized data-acquisition facility. The tantalum alloy (ASTAR-811C) emitter was separated from the niobium - 1-percent-zirconium collector by 0.254 millimeter. This report presents data for an 1800 K emitter, a 1040 K collector, and a 604 to 708 K cesium reservoir. Plots are given of current and power against voltage.

INTRODUCTION

More power at lower temperatures is one of the goals for nuclear thermionic diodes. Providing this improved output requires intensive testing of numerous electrode combinations in cesiated thermionic converters. To ensure success, performance mapping of off-design, as well as optimum operating conditions is required with special attention given to stability. One major contribution toward achieving this goal is to collect, control, and correlate thermionic diode data with a computer (ref. 1). An additional innovation that permits the performance evaluation of a wide range of electrode materials is a miniaturized guarded planar thermionic diode (the diminiode of ref. 2). This diminiode allows evaluations of fragments of rare or monocrystalline elements and compounds approximately half of a centimeter in diameter. This report presents data from the operation of the first diminiode.

The diode has the tantalum-alloy ASTAR-811C (Ta, 8 W, 0.7 Hf, 1 Re, 0.025 C, nominal composition) emitter and a Nb-1Zr collector and guard ring. These alloys are of interest as containment materials for high-temperature heat pipes. And design and fabrication of nuclear thermionic heat pipe systems could be simplified if the heat pipe shells could be used as electrodes for the thermionic converters.

Data were recorded using the computer system described in reference 1. This facility allows the rapid application of a variable transistorized load and makes possible the testing at off-design as well as optimum conditions. Limited data for an 1800 K emitter, a 1040 K collector, and a 604 to 708 K reservoir are presented. Plots are given of current density and power against voltage.

ELECTRODE PREPARATION

Emitter

The ASTAR-811C material used conformed to the specifications of NAS-10200. After grinding the surface flat, the emitter was cleaned in the following solution (vol %) for 30 seconds prior to converter assembly: 5 FH, 10 HNO_3, 15 H_2SO_4, and 70 H_2O.

Collector

The surface of the Nb - 1Zr collector and guard ring were machined to a finish of about (64 μin.) and then ground flat and parallel to each other. The pieces were then cleaned in a solution of trichlorethylene prior to converter assembly.

TEST FACILITY

Test Station

A photograph of the mockup of the planar, guarded, miniaturized converter is shown in figure 1. The interelectrode spacing of 0.254 millimeter was determined from reference surfaces on the emitter and collector body. The diminiode attached to a mounting flange is shown in figure 2. The converter, which was fabricated, processed, and filled with cesium by the procedure discussed in reference 2, was mounted in one of six vacuum test stands that are coupled to a central instrumentation control panel (ref. 3). Each station has its own set of emitter, collector, and cesium-reservoir heat supplies. Thermal balances of the collector and reservoir are achieved through gaseous nitrogen cooling. A schematic diagram of the diminiode thermionic converter is shown in figure 3.

Instrumentation

The current developed in the converter was measured by the voltage drop across either a 0.1 or 1.0 ohm, low-inductance, precision shunt. The output voltage was measured using the sheaths of the cesium reservoir and collector thermocouples as potential probes. The 0.16-square-centimeter collector face determined the current density. The guard ring current lead was electrically connected to the loading circuit so as not to contribute current through the collector current shunt.

Collector and cesium-reservoir temperatures were sensed by sheathed chromel-alumel thermocouples. The couples 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 couple that was referenced electronically to 273 K. Two couples were inserted at each location. The cesium reservoir couples were in the tantalum block surrounding the tantalum tube containing the cesium (see fig. 3). The collector couple was within 5 millimeters of the collector surface.

An automatic optical pyrometer monitored the emitter temperature and provided the emitter temperature trigger input to the data system. An automatic optical pyrometer monitored the outside blackbody hole temperature during the performance mapping tests. This temperature was related to the inner blackbody temperature, representative of emitter surface temperature, during processing. A manually balanced, disappearing filament pyrometer was used to observe the two cavities during the calibration phase.

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 includes the accuracy of the NBS calibration, the reversal capabilities of the optical pyrometer, and the effect of the approximate blackbody cavity in the emitter.

The calibration data indicated that an insignificant change in the two cavity temperatures occurred as the collector temperature was varied over its nominal operating range of 750 to 1100 K. Electron cooling and heating effects on the surface temperatures 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. 1). The contribution of gaseous conduction is negligible.

Test Procedure

The computer-controlled data acquisition system is programmed to monitor the emitter and cesium reservoir temperature and to trigger the variable load whenever these inputs fall within prescribed limits.

For the data presented herein, a single sweep of the current-voltage characteristic at fixed emitter, collector, and cesium reservoir temperatures was used. The detailed operation of the system is described in references 1 and 4.

Preliminary investigations were conducted to determine the effect of emitter, collector, and cesium temperature on performance. Results obtained indicated that high performance could not be achieved by any grouping of temperatures investigated. Consequently, the scope of the test program was reduced accordingly, and only a limited amount of accumulated data are presented.

Data Presentation

Table I lists the temperature conditions for the data presented herein. As shown, the data were taken at an emitter of 1800 K, a collector of approximately 1040 K, and a cesium reservoir range of 604 to 708 K.

TABLE I. - TEMPERATURE CONDITIONS FOR COMPUTER-PROCESSED PLOTS

[Emitter temperature, T_E, 1800 K.]

Collector temperature, T_E, K	Cesium reservoir temperature, T_c, K
1039	604
1037	615
1041	627
1043	641
1042	651
1041	663
1044	676
1043	686
1043	699
1045	708

The Lewis central computer sorts the diode test data and displays them on separate J, V and P, V plots, as well as composites on the microfilm output. The individual J, V and P, V curves are presented in figures 4(a) to (j). The curves, as presented, are the direct output from the computer. The square symbols indicate a change in voltage from right to left; the round symbols are from left to right. Figure 5 summarizes the J, V data for all reservoir temperatures for the selected emitter and collector temperatures.

The current density increases with increases in reservoir temperature up to 651 K. Beyond this value an additional increase in reservoir temperature results in a reduction in current density and output power.

The results of the testing show that the maximum power output of the ASTAR-811C Nb-1Zr electrode combination was 2.5 watts per square centimeter. This level of performance might be acceptable depending on the total integrated system requirement. The observed performance of the alloyed electrodes probably will vary with time as the chemical composition of the surface becomes contaminated due to diffusion of material from the bulk. This process was not investigated during the accumulated testing time of approximately 30 hours.

Finally, at the collector temperature of 1040 K the vapor pressure of the copper braze material (ref. 2) used to attach the collector and guard ring to the cermet insulator is 10^{-7} torr. It is possible that the diode performance could be altered with time by copper contamination of the electrodes. It is believed that this is not a factor because of the short time period used to accumulate the data. To eliminate this as a factor in future electrode performance evaluation programs with the diminiode, the copper has been replaced with a high temperature low vapor pressure eutectic braze material.

CONCLUSION

The performance of a fixed-spaced planar miniature thermionic diode with a tantalum alloy (ASTAR-811C) emitter and a niobium - 1-percent-zirconium collector was mapped using a computerized data-acquisition facility. These data showed a low power output (≤ 2.5 W/cm^2) over the entire range of operation.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, June 8, 1972,
112-27.

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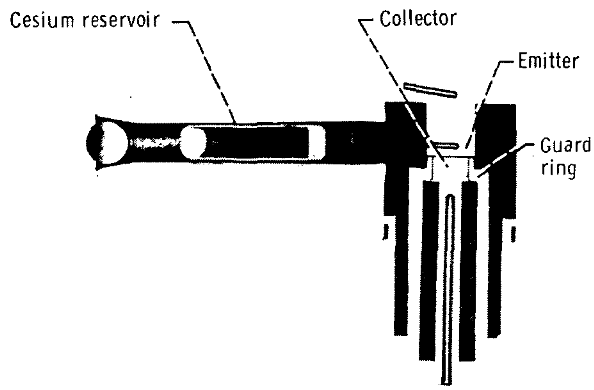


Figure 1. - Converter mockup.

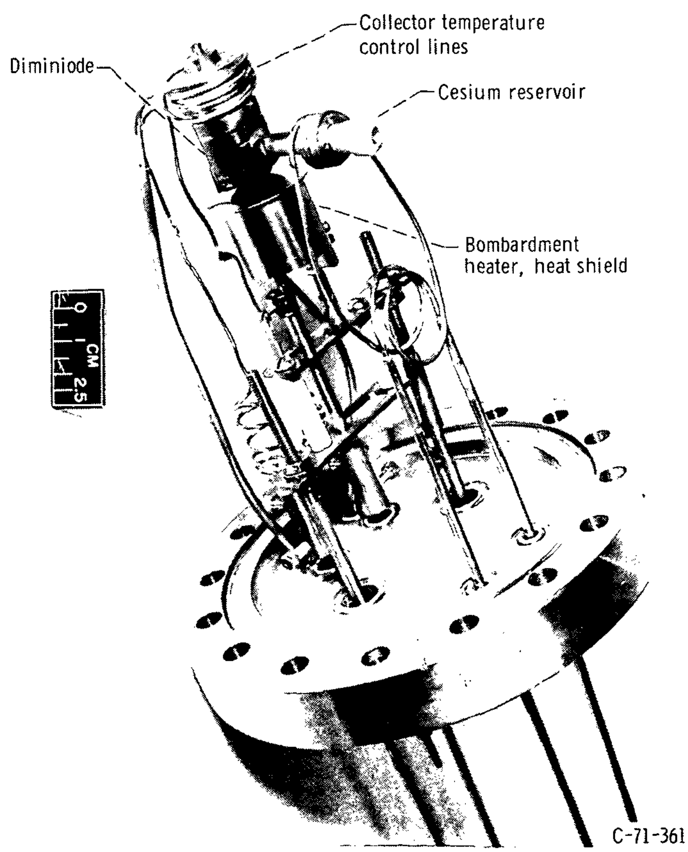


Figure 2. - Diminiode mounted to mounting flange.

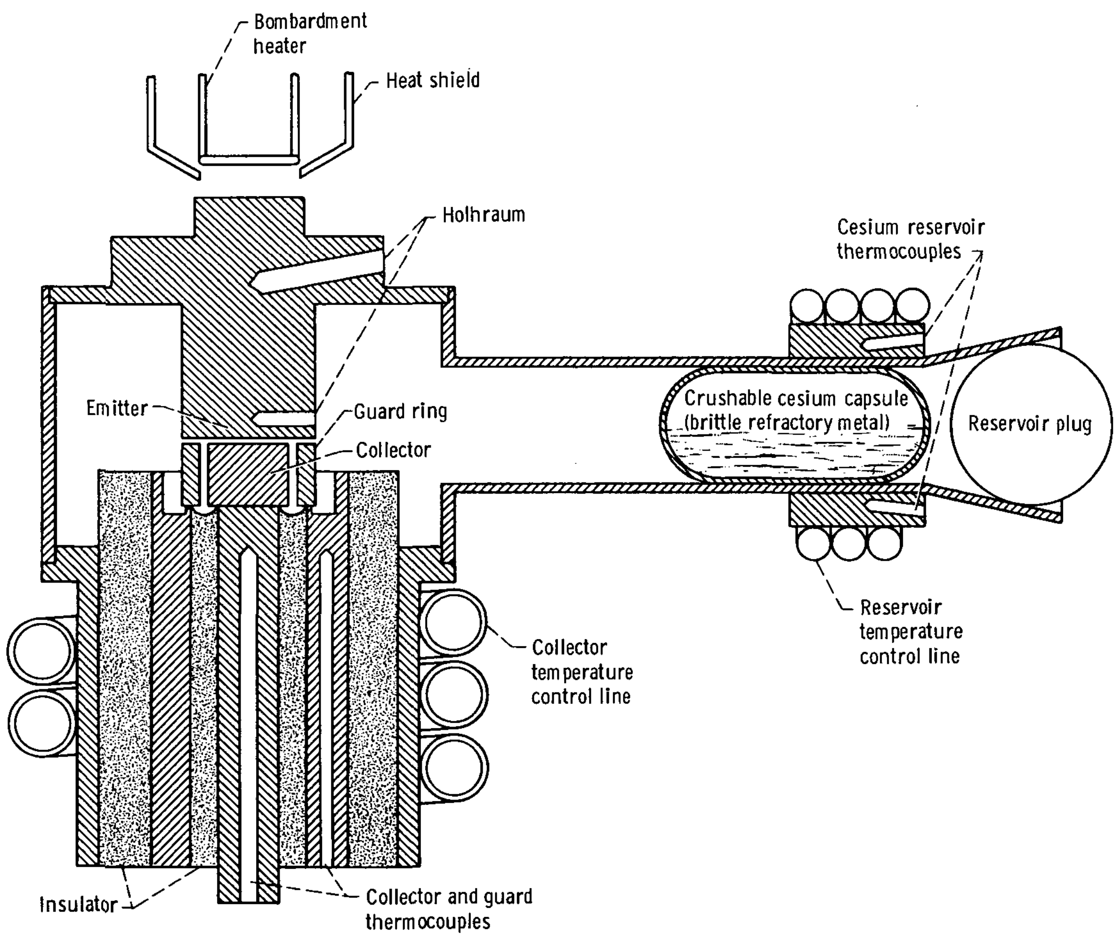
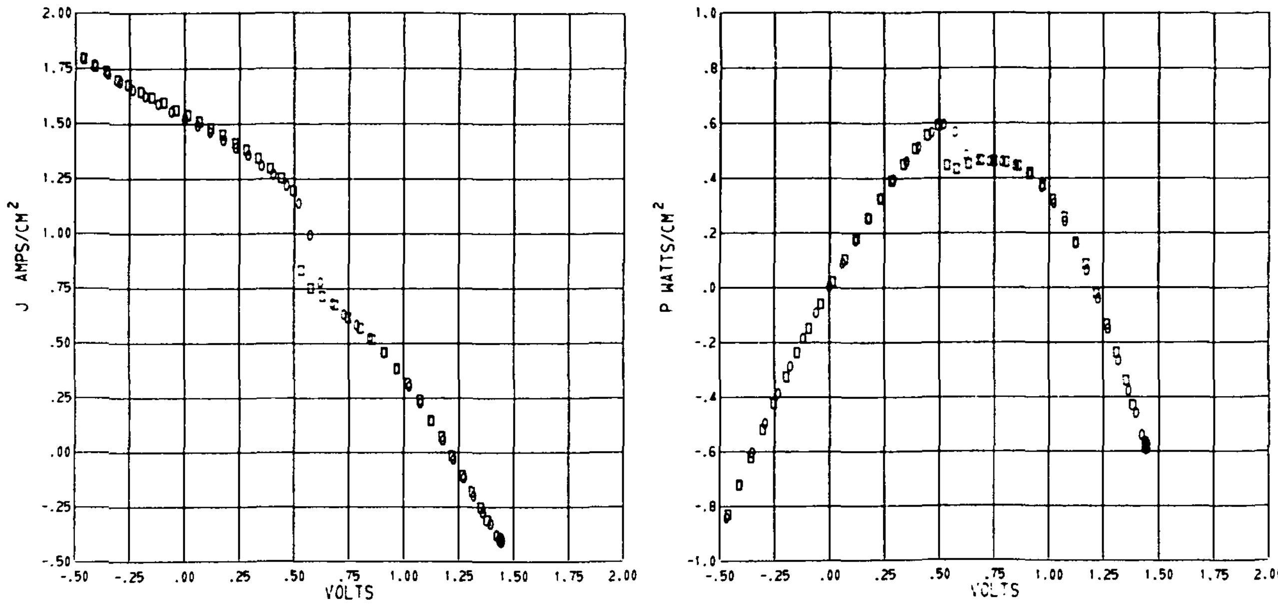
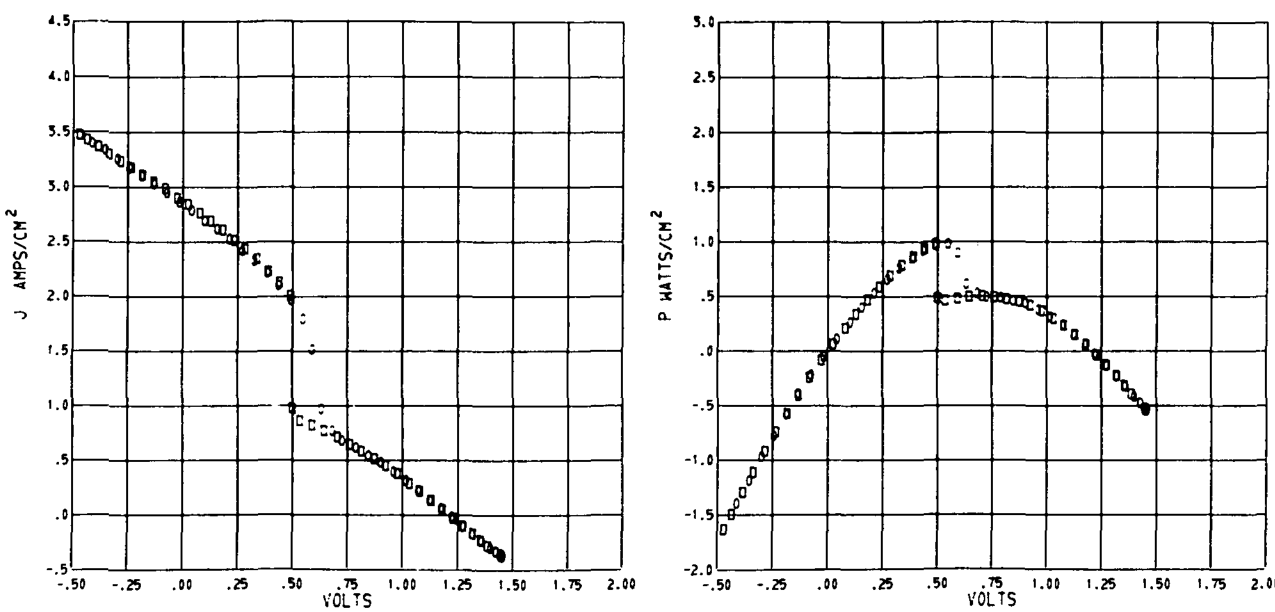


Figure 3. - Schematic diagram of diminiode thermionic converter.

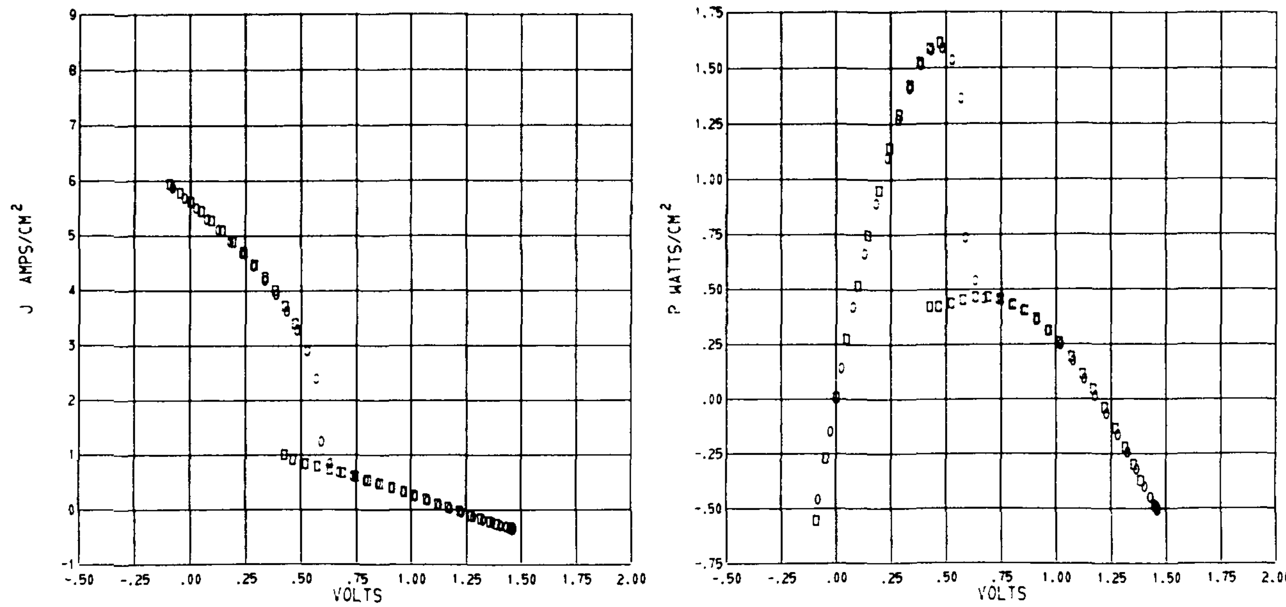


(a) Emitter temperature, 1800 K; collector temperature, 1039 K; reservoir temperature, 604 K; spacing, 10 mils.

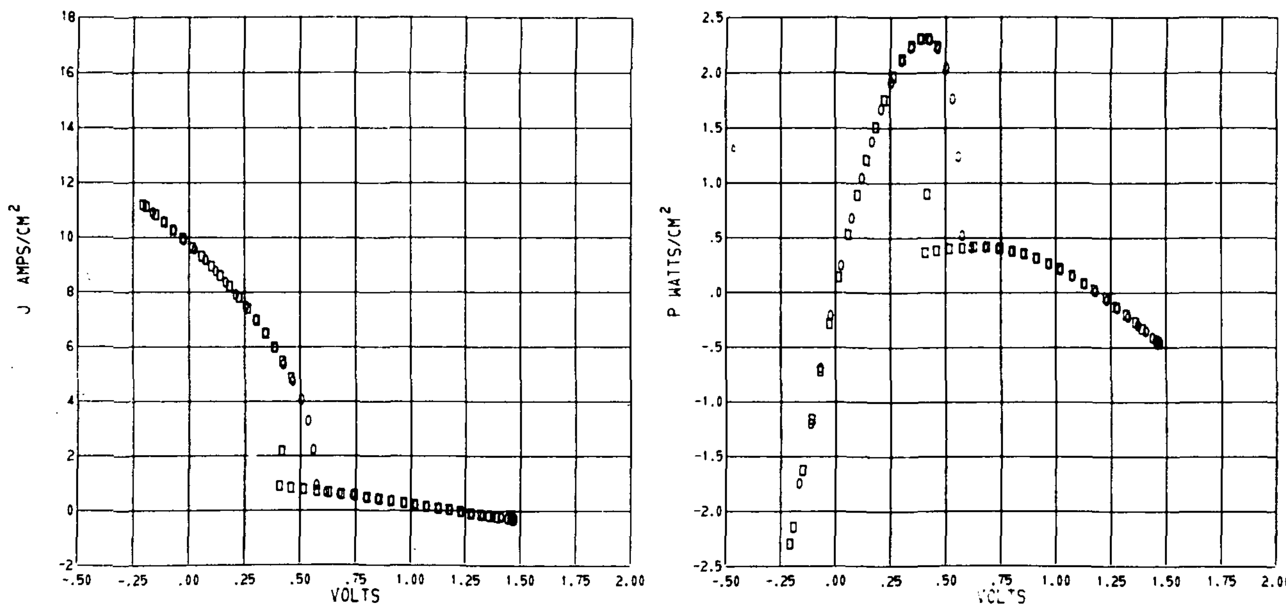


(b) Emitter temperature, 1800 K; collector temperature, 1037 K; reservoir temperature, 615 K; spacing, 10 mils.

Figure 4. - J, V and P, V plots for selected conditions.

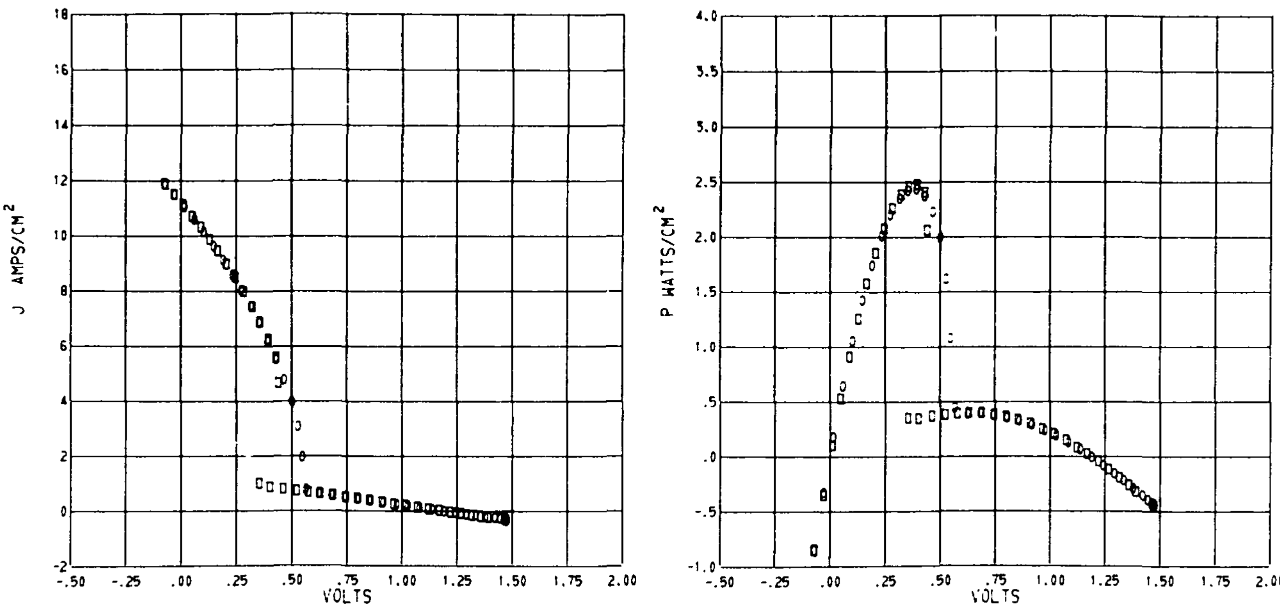


(c) Emitter temperature, 1800 K; collector temperature, 1041 K; reservoir temperature, 627 K; spacing, 10 mils.

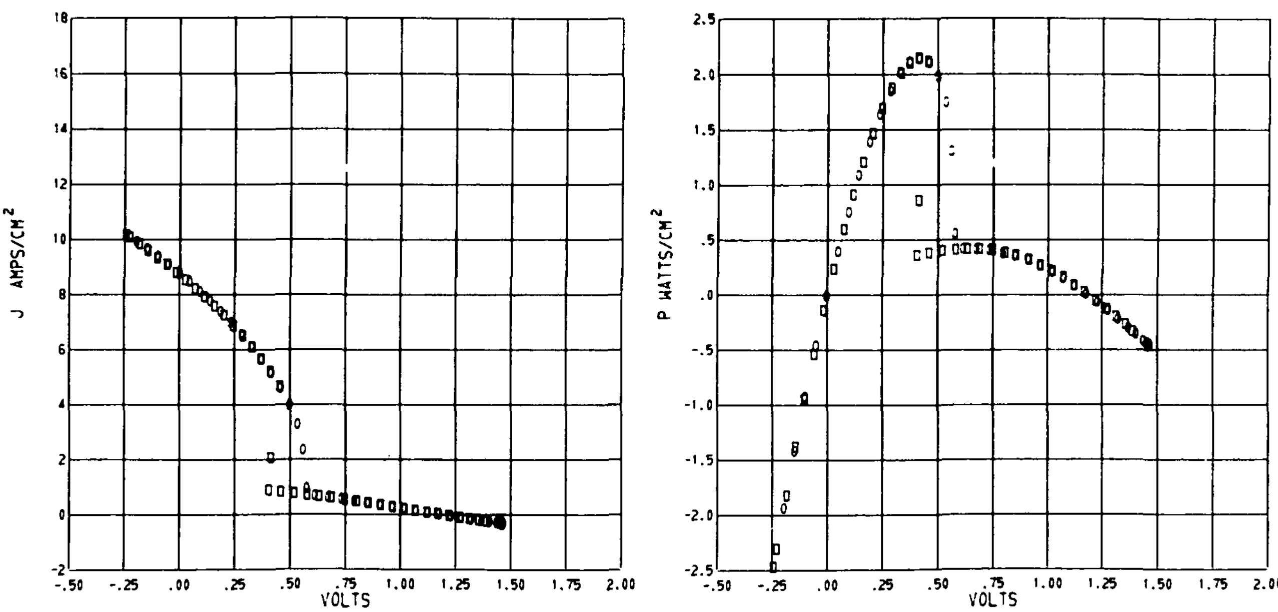


(d) Emitter temperature, 1800 K; collector temperature, 1043 K; reservoir temperature, 641 K; spacing, 10 mils.

Figure 4. - Continued.

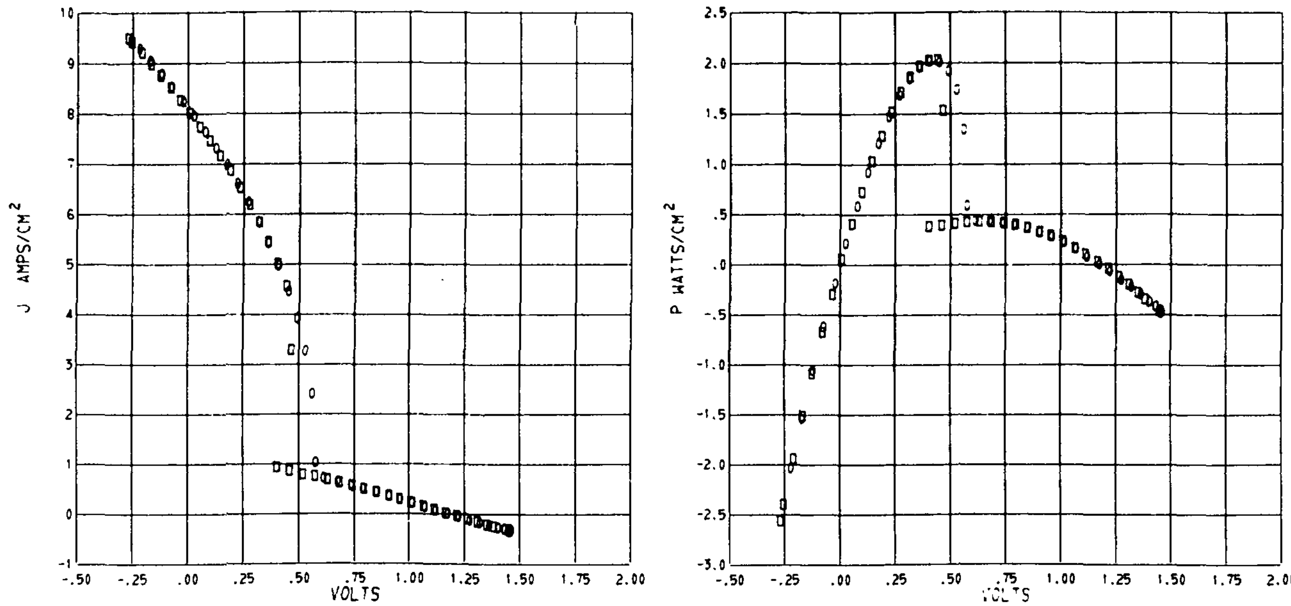


(e) Emitter temperature, 1800 K; collector temperature, 1042 K; reservoir temperature, 651 K; spacing, 10 mils.

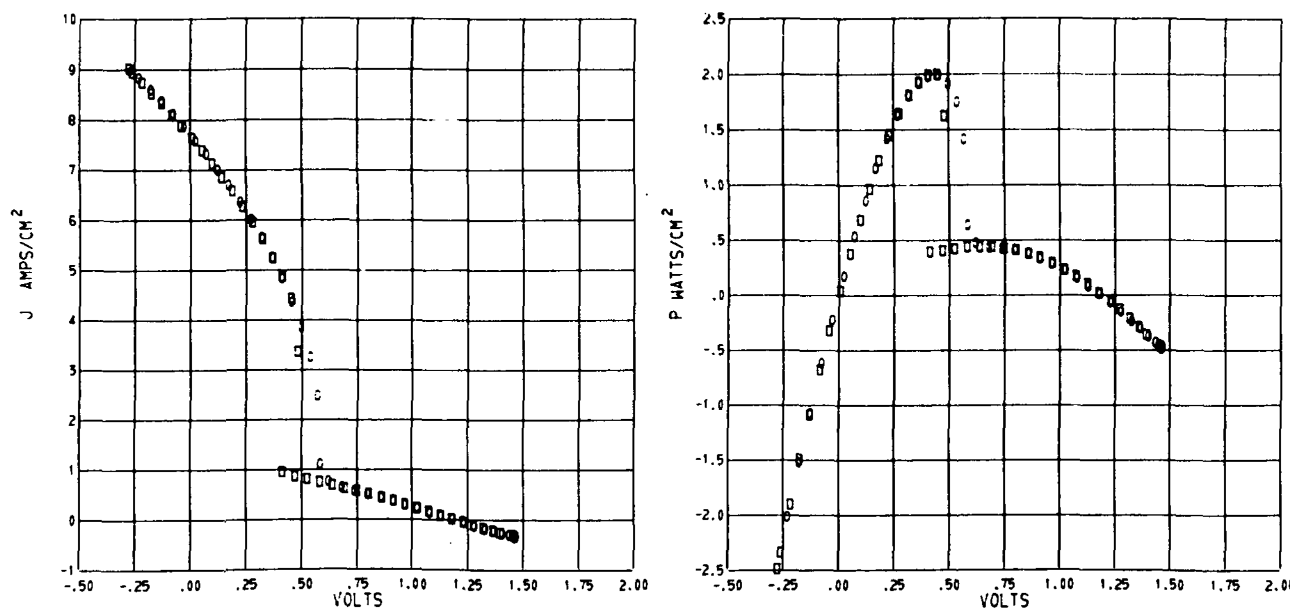


(f) Emitter temperature, 1800 K; collector temperature, 1041 K; reservoir temperature, 663 K; spacing, 10 mils.

Figure 4. - Continued.

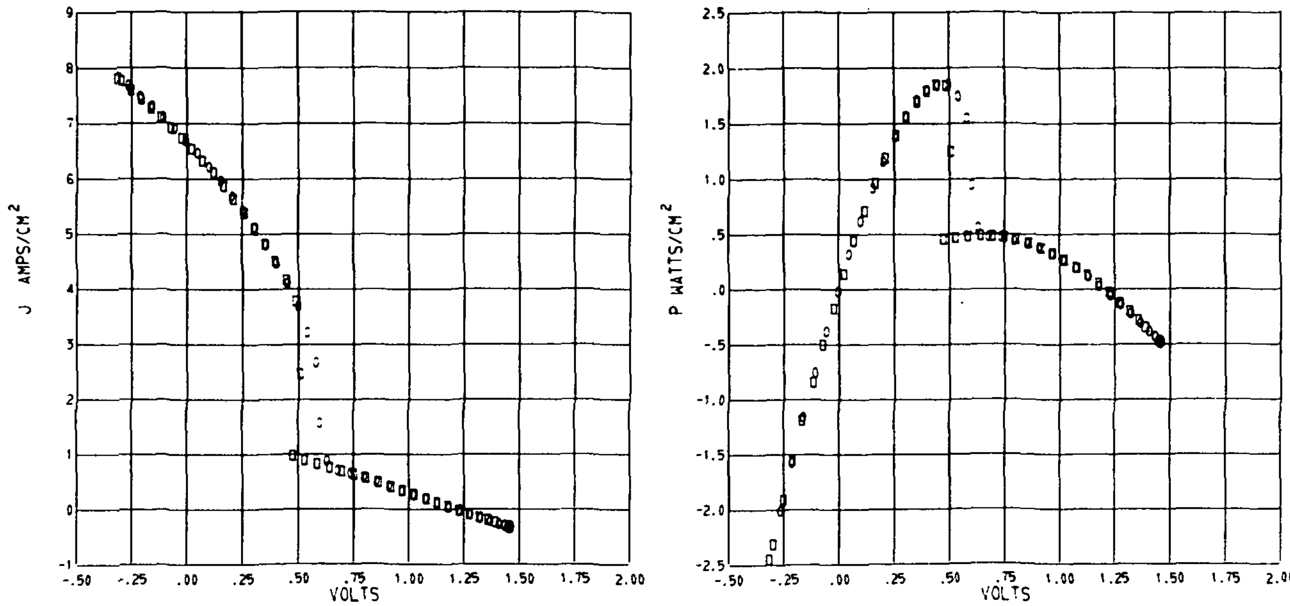


(g) Emitter temperature, 1800 K; collector temperature, 1044 K; reservoir temperature, 676 K; spacing, 10 mils.

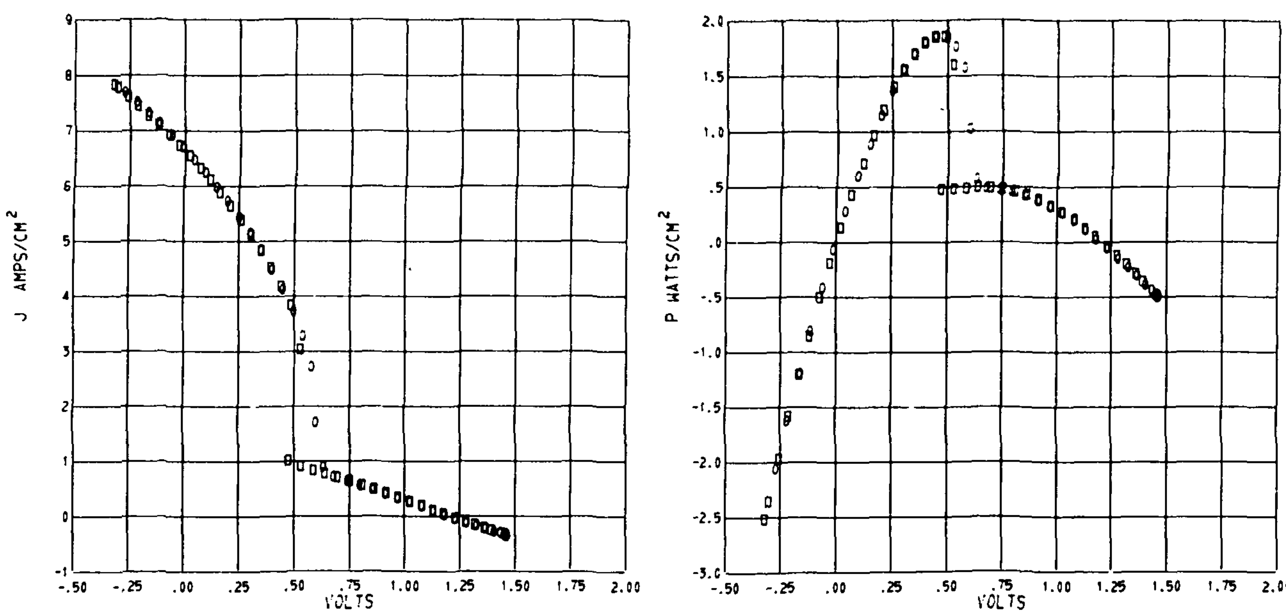


(h) Emitter temperature, 1800 K; collector temperature, 1043 K; reservoir temperature, 686 K; spacing, 10 mils.

Figure 4. - Continued.



(i) Emitter temperature, 1800 K; collector temperature, 1043 K; reservoir temperature, 699 K; spacing, 10 mils.



(j) Emitter temperature, 1800 K; collector temperature, 1045 K; reservoir temperature, 708 K; spacing, 10 mils.

Figure 4. - Concluded.

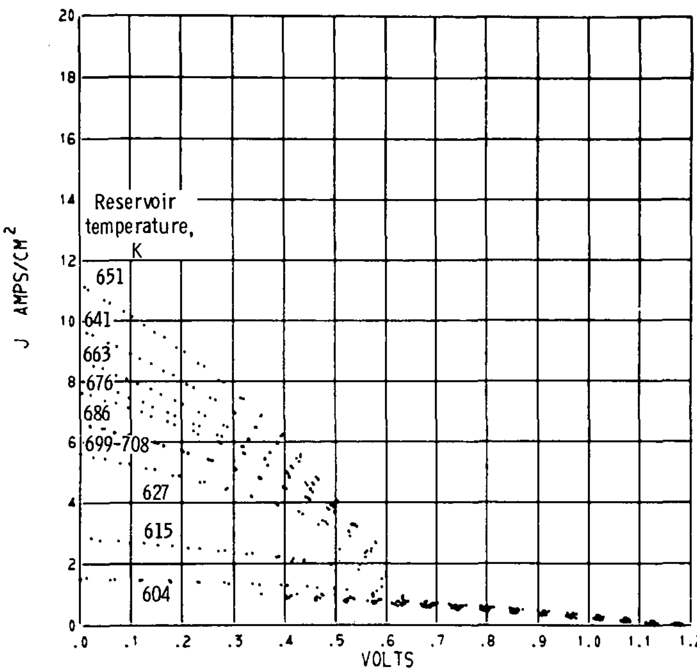


Figure 5. - Emitter temperature, 1800 K; collector temperature, 1040 K; reservoir temperature, 604 to 708 K; spacing, 10 mils.

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