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DIMINIODE THERMIONIC CONVERSION WITH 111-IRIDIUM ELECTRODES

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16. Abstract

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SUMMARY

This report presents preliminary data indicating thermionic-conversion potentialities for a 111-iridium emitter and collector spaced 0.2 mm apart. These results comprise output densities of current and of power as functions of voltage for three sets of emitter, collector, and reservoir temperatures: 1553, 944, 561 K; 1605, 898, 553 K; and 1656, 1028, 586 K. For the 1605 K evaluation, estimates produced work-function values of 2.22 eV for the emitter and 1.63 eV for the collector with a 2.0-eV barrier index (collector work function plus interelectrode voltage drop) corresponding to the maximum output of 5.5 W/cm^2 at 0.24 volt. The current, voltage curve for the 1656 K 111-iridium diminiode yields a 6.2 W/cm^2 maximum at 0.25 volt and is comparable with the 1700 K envelope for a diode with an etched-rhenium emitter and a 0.025-mm electrode gap made by TECO and evaluated by NASA.

INTRODUCTION

This report presents preliminary thermionic-conversion results for a diminiode (ref. 1) with 111-iridium electrodes separated by 0.2 mm. Making both the emitter and collector of the same bulk material counteracts converter vaporization, deposition effects (ref. 2). The choice of 111-iridium derives from "the fact that higher work function (metallic) surfaces are known to provide a lower work function value in the presence of a specified Cs pressure and substrate temperature" (refs. 3 to 5): The bare work function of 111-iridium is 5.76 eV; of 0001 rhenium, 5.34 eV; of 110 tungsten, 5.25 eV; and of 110 molybdenum, 4.92 eV (ref. 3). So of the potential metallic electrodes, 111-iridium promises the lowest cesiated work functions, which means greater current densities from the emitter and greater output voltages from the collector. In addition the vapor pressure of iridium is simular to that of molybdenum, losing less than 10^{-4} mm a year at 1700 K in vacuum (fig. 1). Thus, 111-iridium is an excellent prespect among possible metallic electrodes for cesium thermionic converters.

STAR category 75

This preliminary report is the product of initial testing of a variable-gap diminiode with 111-iridium electrodes: A malfunction terminated the evaluation. And subsequent examination revealed irreparable damage as well as a capillary opening covered by liquid cesium in the end of the reservoir. No other indication of a leak had been apparent. While a replacement diminiode is in process, the present results can serve to indicate the thermionic-conversion potentialities of 111-iridium electrodes. To that end these data represent observed maximum performances corresponding to three sets of emitter, collector, and reservoir temperatures: 1553, 994, 561 K; 1605, 898, 553 K; and 1656, 1028, and 586 K.

As a background reference 6 cites references 7 to 10 on cesium diodes with iridium emitters. References 7 and 8 report 5.5 W/cm^2 for a 1703 K emitter and a 0.76 mm electrode gap. Reference 9 reveals that a 1643 K polycrystalline-iridium emitter 0.23 mm from a stainless-steel collector produced 5.8 W/cm^2 at 0.3 volt and a maximum of 7.2 W/cm^2 at 0.16 volt with about 2 torr of cesium vapor. Adding 60 torr of xenon increased those performances to 7.4 W/cm^2 at 0.3 volt and a maximum of 8.4 W/cm^2 at 0.2 volt. "As before, high cesium pressure with close spacing yields better high-current output at lower voltages, and low cesium pressure with wider spacing yields higher output at higher voltages" (ref. 9). Incidentally reference 10 discusses effects of pulsed discharges of the reference 9 diode.

Enlightened consensus indicates that the usually higher performances found in early thermionic-converter studies probably involved oxygenation effects unrecognized at that time. The same sophisticated opinions propose that additives used in those early studies, particularly inert-gas additions, generally contained oxygen as an impurity. And "the presence of minute quantities of oxygen (10^{-8} to 10^{-6} torr) in a cesium thermionic converter results in improved performance characteristics" (ref. 11). In fact, such observations received support en masse as more effective quality control in diode processing led to lower and lower thermionic-conversion outputs. These findings contributed to the initiation of a program that presently explores oxygenation of cesiated electrodes (ref. 12). And today a practical demonstration of this effect is the increased performance of the TECO cesium, oxygen, tungsten diode over that of the standard nonoxygenated version.

Thus the high power densities of the reference 9 diode undoubtedly redounded at least partially from undefined prductive oxygen effects. The results from the 111-iridium diminiode may also involve some unspecified oxygenation. But the absence of leakage symptoms and the presence of performance levels substantially below those of reference 9, indicate probably negligible additive influences in this diminiode study.

W. E. Frey and R. D. Schaal developed and performed special procedures and conducted research tests necessary to fabricate this diminiode.

EQUIPMENT AND PROCEDURES

Reference 1 provides detailed descriptions of all equipment and procedures used in the experiments treated in this report.

RESULTS

Figures 2 to 4 show selected data representing maximum performances observed in limited initial testing of a diminiode with 111-iridium electrodes spaced 0.2 mm apart. These results comprise output densities of current and power as functions of voltage for three sets of emitter, collector, and reservoir temperatures: 1553, 944, 561 K; 1605, 898, 553 K; and 1656, 1028, 586 K.

Because insufficient data exist to form constant-emitter-temperature envelopes, the present exemplary curves serve only to imply potentialities for thermionic converters with both electrodes made of 111-iridium. For example, outputs reach at least 2.9 W/cm^2 at 0.14 volt for a 1553 K emitter, 5.5 W/cm^2 at 0.24 volt for 1605 K, and 6.2 W/cm^2 at 0.25 volt for 1656 K.

Work function estimates for the 1605 K test are 2.22 eV for the emitter and 1.63 eV for the collector. These values compare with 2.38 and 1.54 eV for cesiated rhenium at appropriate electrode-to-reservoir temperature ratios of 2.9 and 1.6 (ref. 13). The work functions for this 1605 K 111-iridium diminiode indicate a barrier index (collector work function plus interelectrode voltage drop) of 2.0 eV corresponding to the 5.5-W/cm^2 maximum.

Figure 5 reveals that the 1656 K current, voltage curve is similar to the better 1700 K envelope for diodes with etched-rhenium emitters and 0.25-mm electrode gaps made by TECO and evaluated by NASA (ref. 14).

Such results merit further investigation: Another 111-iridium diminiode is now in the fabrication process.

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VAPORIZATION OF PURE METALS AND LANTHANUM HEXABORIDE

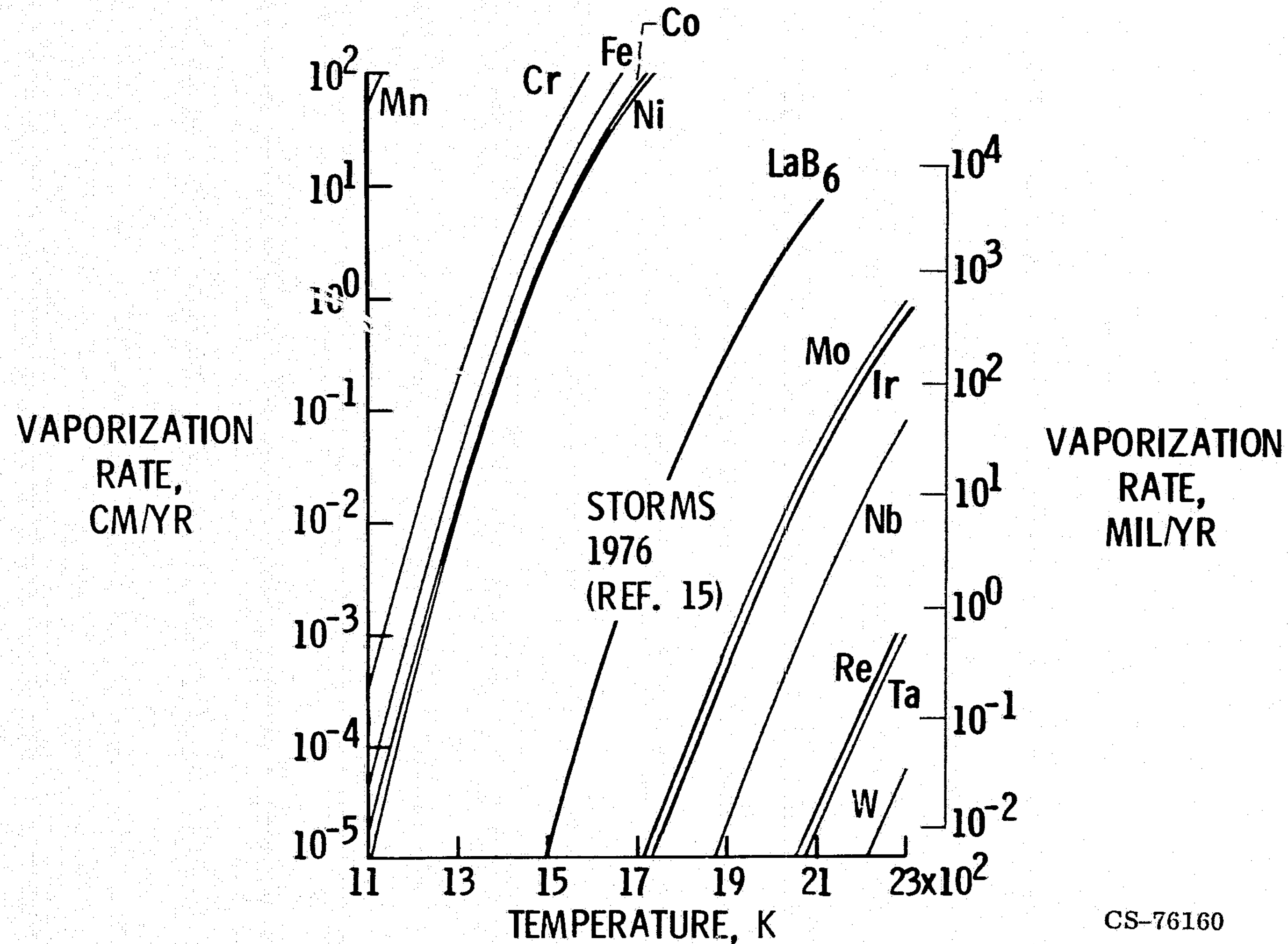

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FIGURE 1

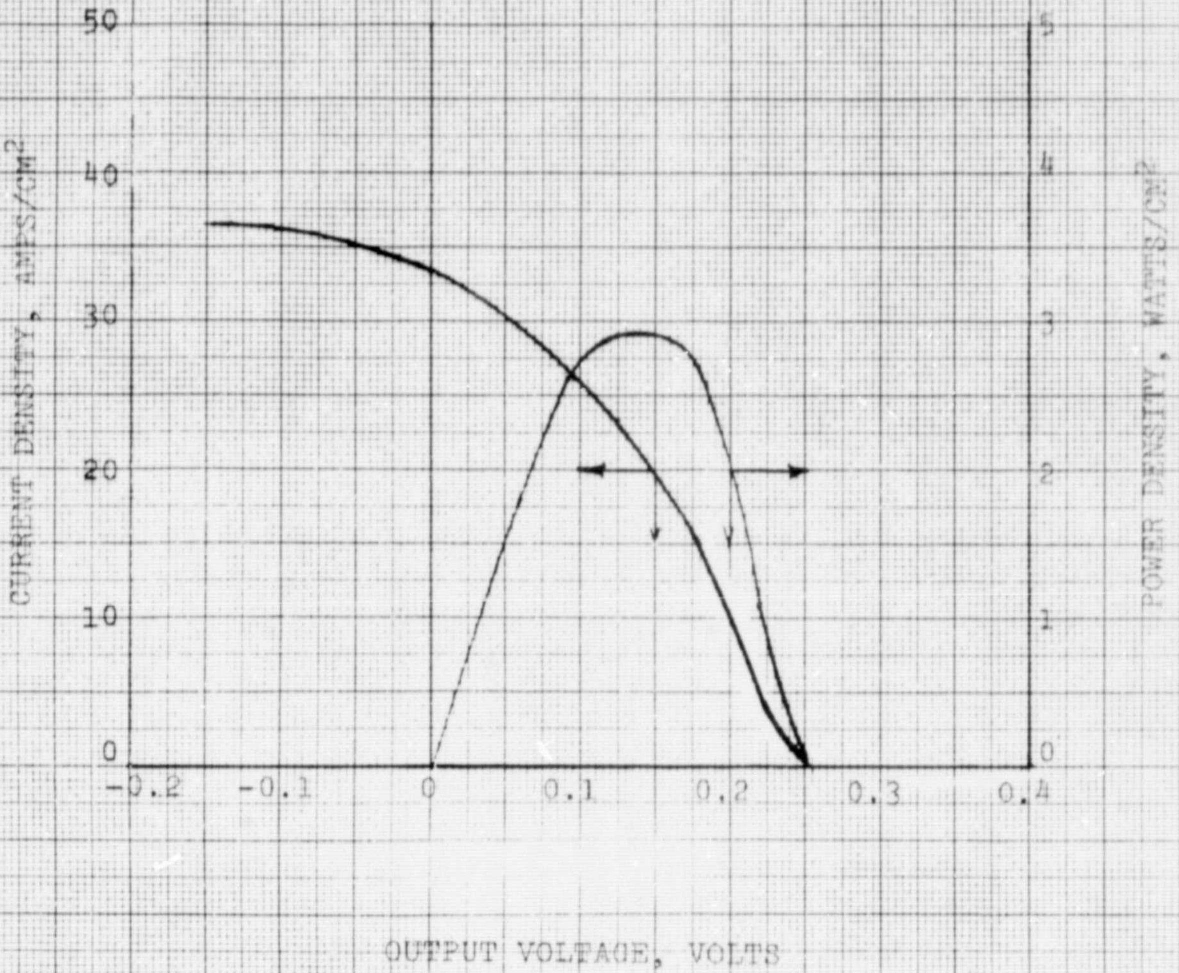

FIGURE 2

DIMINIODE OUTPUTS FOR 111-IRIDIUM ELECTRODES 02 MM APART
(1553K EMITTER, 944K COLLECTOR, 561K CESIUM RESERVOIR)

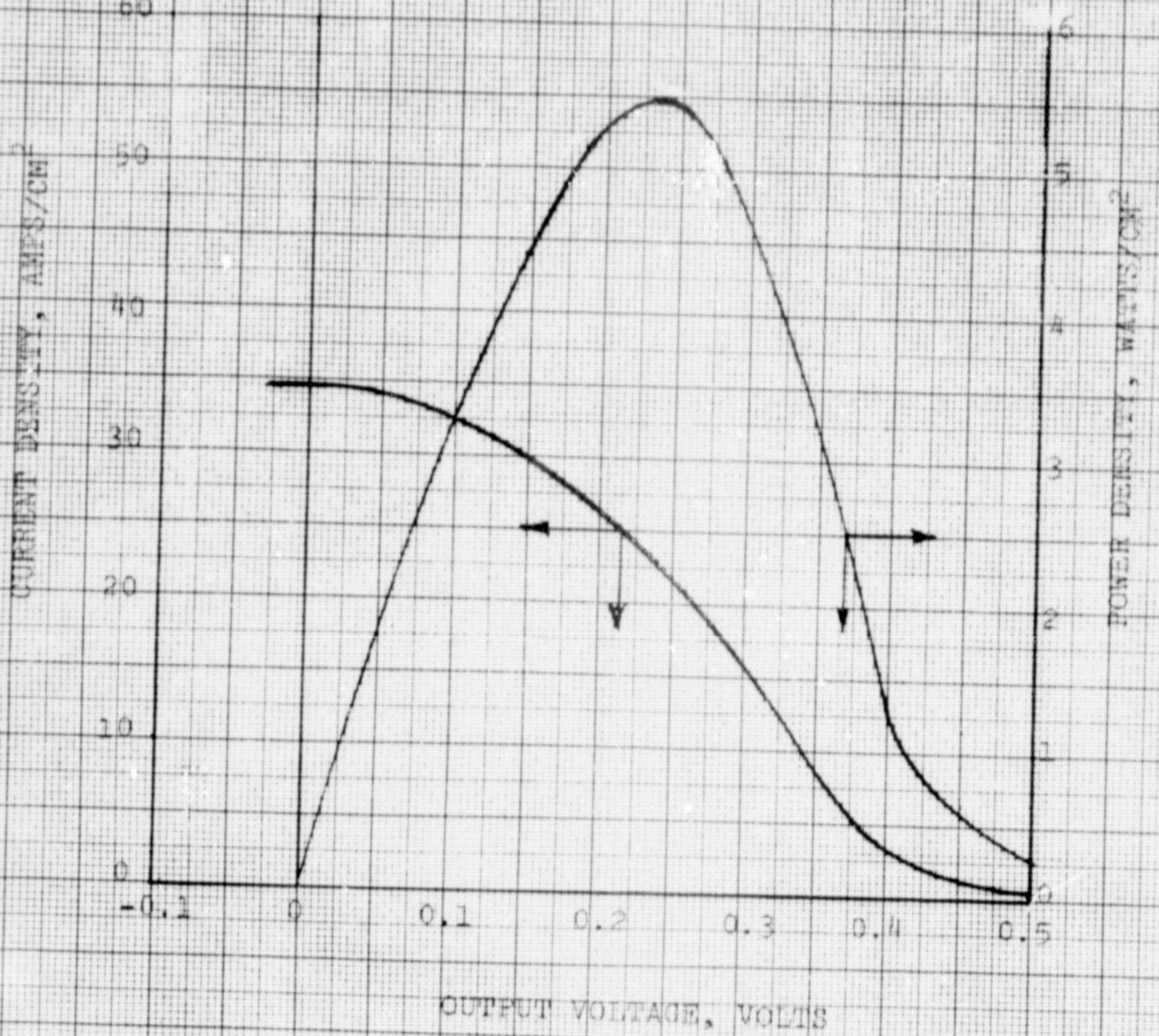

FIGURE 3, DIMINIODE OUTPUTS FOR 111-IRIDIUM ELECTRODES 0.2MM APART (1605K EMITTER, 898K COLLECTOR, 553K CESIUM RESERVOIR)

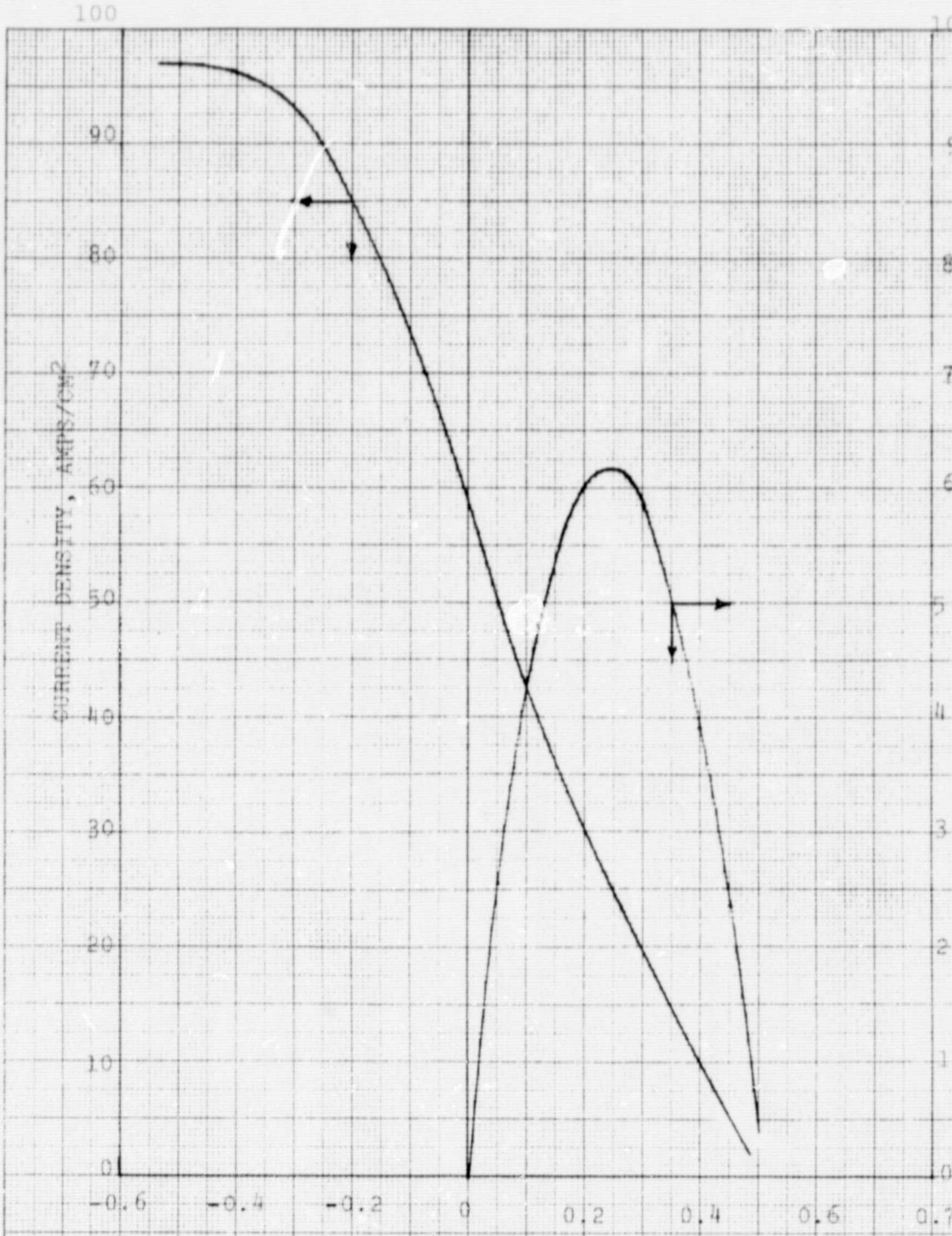

FIGURE 4. DIMINIODE OUTPUTS FOR 111-IRIDIUM ELECTRODES 0.2MM APART (1656K EMITTER, 1028K COLLECTOR, 586K CESIUM RESERVOIR)

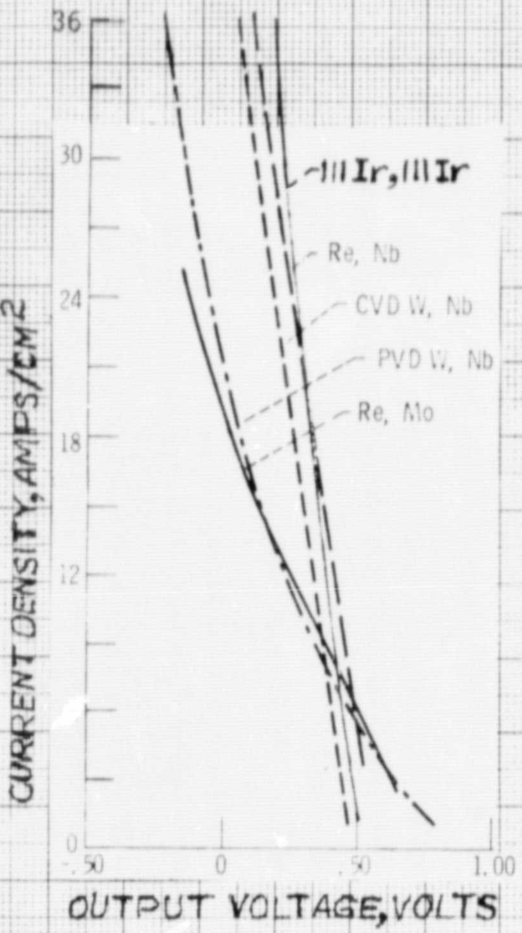

FIGURE 5: A COMPARISON OF 1700K-EMITTER (0.25MM-GAP) ENVELOPES (REF. 14) WITH DIMINIODE OUTPUTS FOR 111-IRIDIUM ELECTRODES 0.2MM APART (1656K EMITTER, 898K COLLECTOR, 553K RESERVOIR)

J.F. MORRIS 7/15/76