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CORRELATION EXPRESSION FOR THE PERFORMANCE OF AN ETCHED-RHENIUM EMITTER, NIOBIUM COLLECTOR, CESIATED THERMIONIC CONVERTER

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SUMMARY

An equation is presented that correlates current, voltage, emitter temperature, and collector temperature of a cesiated thermionic converter using an etched-rhenium emitter and a niobium collector.

INTRODUCTION

The effect of the emitter temperature and collector temperature on thermionic converter performance must be known in order to design an effective thermionic power system. Performance surveys of various combinations of electrodes are now being obtained with the degree of detail needed for a reliable system analysis (e.g., refs. 1 and 2). Since the experimental survey usually involves over 500 current, voltage curves, the direct use of the experimental data is unwieldly. An interpolative-analytical compaction of the data is required.

Although complex analytical forms based on detailed theory are instructive, they are not amenable to system studies. The description of the performance must be kept simple and adaptable to a variety of computational procedures. This report presents such an expression that fits the data of reference 1 and a more recent data compilation by E. J. Manista of Lewis. Voltage is related to current density from 3 to 30 amperes per square centimeter at emitter temperatures of 1750 to 1900 K and at collector temperatures of 800 to 1000 K for the cesium pressure that provides maximum performance. The data used are for an etched-rhenium emitter, niobium collector, in a converter of 10 mil interelectrode spacing.

DATA ANALYSIS

The data were machine sorted to select the maximum current density at a given output voltage with varying cesium pressure for constant emitter temperatures T_E of 1750, 1800, 1850, and 1900 K and constant collector temperatures T_C of 800, 850, 900, 950, and 1000 K. Two typical plots at emitter temperatures of 1750 and 1850 K appear in figures 1 and 2. The data are limited to current densities of 3 to 30 amperes per square centimeter, the range of interest of practical converters.

Several characteristics of the data suggest a form for the correlating expression: (1) the linear shape of the current, voltage curves that represent maximum performance, (2) the regular increase in output voltage with an increase in collector temperature at the higher current densities (the effect of changes in collector work function), and (3) the combined effects of decreased collector work function and increased collector temperature in producing back emission that in turn decreases the net current.

The relative effect of back emission at the high current is of course reduced both by

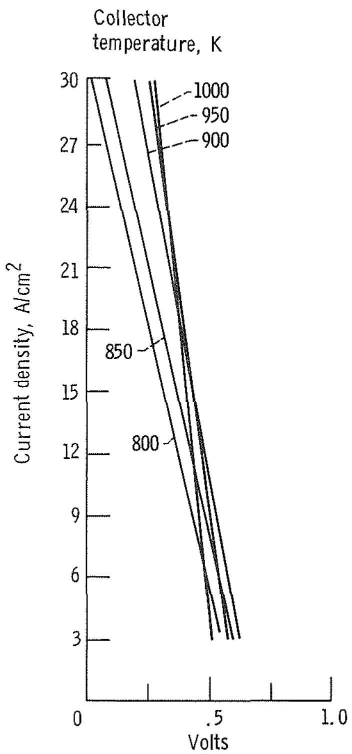

Figure 1. - Maximum performance at emitter temperature of 1750 K with cesium reservoir temperature varied from 562 to 639 K.

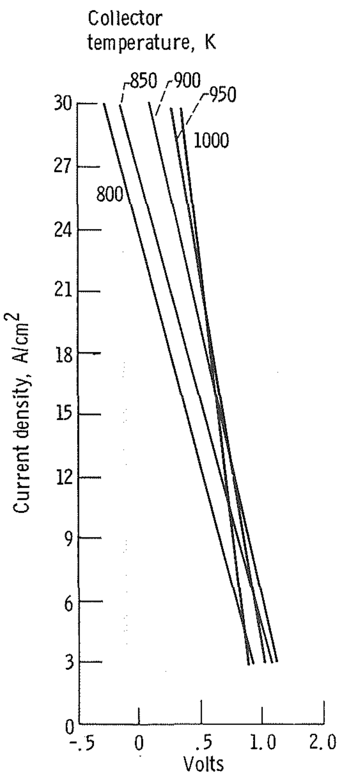

Figure 2. - Maximum performance at emitter temperature of 1850 K with cesium reservoir temperature varied from 559 to 641 K.

the ratio of forward to back emission current and the influence of the increased barrier to return flow at the lower output voltages. If it were not for the back emission effect (see 800 and 850 K collector temperature curves) a remarkably simple correlation would exist.

The pattern used in developing the empirical fit was to start simply and ignore the effect of back emission. The first three bracketed terms in equation (1) neglect back emission. A corrective term that linearly compensates for the influence in back emission, the fourth bracket, completes the correlation.

$$V = \left[1.49 - \frac{T_E}{T_C}(0.63)\right] + \left(\frac{3.25\ T_E}{1800} - 3.25\right) + \left[\left(\frac{0.0377\ T_E - 47.55}{1000}\right)(30 - J)\right] - \left[(30 - J)\frac{(T_C - 860)}{12\ 000}\right] \quad \text{for} \quad T_C > 860 \tag{1}$$

A random check of the expression indicates the voltages are within ±20 millivolts of a recent extensive data compilation by E. Manista of Lewis with a few exceptions at an emitter temperature of 1900 K.

CONCLUDING REMARKS

A simple expression is available that correlates the current, voltage performance of a fixed spacing, cesiated, thermionic converter using an electro-etched emitter and a niobium collector.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, June 25, 1971,
120-27.

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