

I. PHYSICAL ELECTRONICS

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A. AIDS FOR THE ANALYSIS OF THERMIONIC ENERGY CONVERTERS

Experimental data describing the electrical performance of the thermionic energy converter that is operated in the presence of cesium vapor generally include:

1. The emitter temperature.
2. The collector temperature.
3. The area of the emitter.
4. The area of the collector.
5. The spacing, emitter to collector.
6. The cesium temperature.
7. Emitter material.
8. Collector material.

This list represents the controllable parameters; and the principal observations made involve the determination of a current-voltage curve with all of the parameters held constant, except for the applied voltage. The current then becomes the dependent variable.

The questions that an analysis would hope to answer include the following:

1. What is the work-function of the emitter, and does it remain constant throughout the full range of applied voltage?
2. What is the collector work-function, and does it remain constant during the entire range of applied voltage?
3. Are ions generated at the emitter surface?
4. Do these ions pass freely into the emitter-collector space, or are they inhibited by the presence of a positive ion space charge at the emitter?
5. If there is no positive ion space charge, is there an electron space charge that inhibits the flow of electrons into the space?
6. Do the electrons that do enter the space generate more ions by collision, and what is the ionization process: a single step ionization, or an atomic excitation followed by ionization? Can electrons or light ionize atoms at a surface?
7. If the electrons do excite or ionize the gas, do they get their energy by passing through the positive ion space-charge sheath, or did they get that energy as a result of the application of a collector potential capable of accelerating electrons?
8. Does the mode of generating ions in the space for a given applied potential depend on the sequence of events before the application of that potential?
9. Does the observation of the open-circuit voltage yield information helpful to the analysis of converter performance?

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10. Can the reverse current characteristic of the diode aid in its analysis to give information on ion production rates, or ion loss rates, as the case may be?

11. Can observations taken with the collector biased positive with respect to the emitter contribute to an understanding of converter performance, since the device acts as an energy converter only when the collector is biased negative with respect to the emitter.

This list covers a large number of questions which an experimenter would like to have answered in order to understand the performance characteristics of a thermionic energy converter. It is seldom possible to answer many of these questions, and considerable detailed analysis must be undertaken in order to accomplish even a tentative analysis of conversion performance. In every case there are certain relations that are generally expressible in equation form which must be evaluated over and over again.

A report is now in preparation to present facts based on the latest available data, together with graphical means for obtaining answers quickly with all of the required accuracy. The tables and charts include:

1. Thermionic emission data as computed at various temperatures for a wide range of limiting barriers or work-functions.
2. Cesium "pressure" data expressed in a variety of ways which include:
 - (a) equilibrium pressure as a function of temperature of the liquid.
 - (b) atom concentration as a function of temperature.
 - (c) atom arrival rate as a function of temperature expressed both in terms of the number of atoms per unit area and the ion current that this number of atoms would produce if all of them became ionized.
 - (d) electron mean-free path expected in a region of some specified temperature equal to or higher than the cesium condensation temperature.
3. The relation between emitter temperature and cesium temperature for idealized space-charge neutralization at surfaces of different work-function as the parameter.
4. Average properties of tungsten surfaces at specified temperatures in the presence of cesium arriving at the surface and controlled by some specified condensation temperature of the cesium. The charts presented depend on the Taylor-Langmuir data and on Houston's data.¹
5. Similar charts for tantalum in the presence of cesium based on Houston's data.
6. Similar charts for molybdenum in the presence of cesium based on Houston's data.
7. Examples of these aids in the analysis of converter data.
8. Fundamental atomic constants and many useful combinations of these constants are evaluated.

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References

1. J. M. Houston, Thermionic Emission from Refractory Metals in Cesium Vapor, Report of Proceedings of the Round Table Discussion on Cathode Emission Investigations and Experimental Techniques for Fabricating and Operating Thermionic Cells, Report PIC-ELE-T13/3, Power Information Center, University of Pennsylvania, Philadelphia, Pennsylvania, 30 June 1961.

