DRAFT COPY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Report No. TE4258/4247-135-79

DOE/JPL
ADVANCED THERMIONIC
TECHNOLOGY PROGRAM

PROGRESS REPORT NO. 38

February - March 1979

DOE Contract EY-76-C-02-3056
JPL Contract 955009

Prepared by

Thermo Electron Corporation
101 First Avenue
Waltham, Massachusetts 02154

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Handwritten signature

PART ONE: DOE TASKS

I. SURFACE AND PLASMA INVESTIGATIONS

A. SURFACE CHARACTERIZATION CHAMBER EXPERIMENTS

The properties of polycrystalline $\text{LaB}_{6.5}$ with coadsorbed cesium and oxygen were determined. Lanthanum hexaboride with this stoichiometry is reported⁽¹⁾ to possess a high electron emission flux and a low evaporation rate and is thus an interesting candidate material for thermionic converter electrodes. The work function and reflection coefficients were measured by the FERP method, and surface composition was determined by Auger analysis. The results were remarkably similar to the properties of polycrystalline iridium with coadsorbed cesium and oxygen, as given in the last bimonthly report.

The work functions and surface coverages for the surface as received, after sputtering and after heating to 1700 K, are given in Table I. The as-received surface has a work function of 4.8 eV and contains large carbon and oxygen impurities and a small amount of magnesium, the latter due to the packing material. Sputtering greatly reduces the carbon and oxygen concentrations and lowers the work function to 3.51 eV. Heating to 1700 K

TABLE I
SUMMARY OF LaB_{6.5} DATA

Properties	As Received	Sputtered*	Heated 1700 K**	Cesium	Cesium plus Oxygen
Work Function	4.80 eV	3.51 eV	3.26 eV	1.82 eV	1.04 eV
Surface Coverages†					
Cs ₅₆₃	—	—	—	9%	81%
O ₅₁₀	19%	4%	1%	2%	19%
B ₁₇₉	33%	69%	74%	62%	—
La ₆₂₅	26%	21%	25%	24%	—
C ₂₇₃	17%	4%	0.2%	3%	—
Mg ₁₁₇₄	5%	3%	—	—	—
Ar ₂₁₅	—	1%	—	—	—

*Sputtering parameters: time = 7 min., I = 25 mA, V = 2 kV,
P = 5 x 10⁻⁵ torr Argon.

**Average of four runs.

†Subscripts on elements denote energy in electron volts of Auger peak used to calculate coverages.

after thorough degassing of the emitter assembly gives a clean $\text{LaB}_{6.5}$ surface with a work function of 3.26 eV.

The maximum heating temperature obtainable was 1700 K due to the large size of the emitter assembly. Heating to 2000 K would probably be necessary to obtain a work function of 2.9 eV.

It is of interest to note that under many various sputtering and heating conditions, before cesium is deposited, the work function of $\text{LaB}_{6.5}$ depends primarily on the oxygen concentration. High work functions correspond to high oxygen concentrations, and low work functions to low oxygen concentrations. In contrast, the carbon concentration has no clear effect on the work function.

Deposition of cesium on the $\text{LaB}_{6.5}$ emitter assembly produced a work function of 1.8 eV using the FERP technique. A plot of I (collector current) versus V (collector voltage) for this cesiated surface and for a clean $\text{LaB}_{6.5}$ surface is shown in Figure 1. The reflection is small, similar to cesium on polycrystalline iridium. Additional cesium doses increased the work function to 1.95 eV, and a subsequent oxygen exposure of 7×10^{-6} torr-sec increased the work function to 2.52 eV.

Figure 1. FERP Collector Current Versus Collector Potential for Cesium on $\text{LaB}_{6.5}$.

Simultaneous dosing of cesium and oxygen was employed next, as described in the last bimonthly report. Figure 2 shows I versus V curves for $\text{LaB}_{6.5}$ after cleaning and after a simultaneous cesium-oxygen dose. A low work function of 1.04 eV was obtained, which is essentially the same work function as obtained for polycrystalline iridium with coadsorbed cesium and oxygen (1.05 and 0.95 eV). In addition, the reflection curves (obtained from I versus V characteristics) are quite similar for $\text{LaB}_{6.5}$ and iridium, as seen in Figure 3. This correspondence in reflectivity holds for the clean surfaces, for the cesiated surfaces, and for surfaces with coadsorbed cesium and oxygen. For both $\text{LaB}_{6.5}$ and iridium the reflectivities at threshold are less than 0.16 for the clean surface and the cesiated surface. However, for both substrates, the threshold reflectivities are about 0.5 for the cesium- and oxygen-covered surfaces. Such high reflectivities could have a significant influence on thermionic converter performance.

Auger analysis of the low work function $\text{LaB}_{6.5}$ surface shows only cesium and oxygen, with no lanthanum or boron present (see Table I). This indicates a thick cesium-oxygen overlayer, which was also inferred from the

Figure 2. FERP Collector Current Versus Collector Potential for Cesium Plus Oxygen on $\text{LaB}_{6.5}$.

Figure 3. Reflectivities of LaB_{6.5} and Iridium Versus Electron Energy.

iridium data. In addition, the low cesium and oxygen coverages for the $\text{LaB}_{6.5}$ sample (Cs-81%, O-19%) and the iridium sample (Cs-80%, O-14%) are very similar.

B. SPECTROSCOPIC PLASMA MEASUREMENTS

Spectroscopic measurements were taken on Converter No. 212 to determine the plasma parameters in the mesa and groove regions. The experimental arrangement is shown in Figure 4. Radiation emitted from the inter-electrode space was focused by a 124 mm focal length lens ($f/7.7$) into the 1/2-meter monochromator ($f/8.6$). The photomultiplier tube used was Hamamatsu Multialkali Model R818 (1850 - 8800 Å). The monochromator and the condensing lens were on a translational mechanism so that the radiation along the grooved emitter surface could be scanned and measured.

Electron density was determined by Stark broadening. The $5D_{5/2} - 8F_{7/2}$ transition (6628.7 Å) of cesium was used. Electron temperature was determined from the relative recombination radiation measurements of the continuum to 6P level transitions. In addition, the cesium excited states density distributions were determined by the $nD_{5/2} - 6P_{3/2}$ and $nF_{7/2} - 6D_{5/2}$ transitions of the cesium atoms.

Figure 4. Spectroscopic Measurement Arrangement for the Hybrid Converter (Dotted Lines are for Pulsed Operation).

The results on the spectroscopic measurements of Converter No. 212 are shown in Figures 5 and 6. These data were used to determine the electron and excited state temperatures. Notice that the lower excited states of cesium have higher temperatures than the temperatures determined by the higher excited states.

During the spectroscopic measurements, the converter was operated at an emitter temperature of 1600 K, a collector temperature of 850 K and a cesium reservoir temperature of 544 K. The results from the spectroscopic measurements are summarized in Table II. Within the experimental error, there was no difference in the plasma parameters between the mesas and the grooves.

C. CONVERTER THEORY

With the removal of the assumption that the electron current equals the total current through the plasma,⁽²⁾ the Thermo Electron plasma program can provide solutions with lower values of current ratio, J/J_s . In addition, the calculated J-V curve gives a better match with the measured characteristic. However, an unexpected behavior of the electron temperature distribution was observed, as shown in Figure 7. At low output current, the electron

Figure 5. Electron Temperature Determined from 6P Continuum Measurements.

Figure 6. Relative Excited State Population Density in Cesium Discharge (Solid Lines Determine the Excited State Temperatures).

TABLE II
SUMMARY OF THE PLASMA PARAMETERS IN THE HYBRID CONVERTER*

SPACING (mm)			1.00			0.28	
CURRENT DENSITY (A/cm ²)			8	4	0.6	8	0.6
MESA	Plasma Density	N _e (1/cm ³)	1.5 x 10 ¹⁴	1.1 x 10 ¹⁴	7.5 x 10 ¹³	1.0 x 10 ¹⁴	7 x 10 ¹³
	Electron Temp.	T _e (K)	2600				
	Excited State Temp.	T _a (K)	1700	1700	1700	1700	
GROOVE	Plasma Density	N _e (1/cm ³)	1.5 x 10 ¹⁴	1.2 x 10 ¹⁴	7.5 x 10 ¹³	1.1 x 10 ¹⁴	7 x 10 ¹³
	Electron Temp.	T _e (K)	2600	2200			
	Excited State Temp.	T _a (K)	1700	1700	1700	1700	

*Operating Conditions: Emitter Temperature of 1600 K
Collector Temperature of 850 K
Reservoir Temperature of 544 K

Figure 7. Electron Temperature Distribution as a Function of Current Density, J .

temperature increases as it approaches the collector. This same phenomenon had been observed by Lieb and Bornhorst⁽³⁾ in their analysis of the thermionic diode. They suggested that it is due to the additional $1/2 kT_e$ appearing in the energy transport equation ($5/2 kT_e$) and not in the half-Maxwellian distribution ($2 kT_e$) of the electron leaving the plasma. That is,

$$U_e = \left(\frac{5}{2} kT_e + \psi \right) \Gamma_e - \kappa \frac{dT_e}{dx} \quad (1)$$

and at the collector boundary,

$$U_e = (2 kT_e + \phi_C) \Gamma_e \quad (2)$$

However, if Equation (1) and (2) are combined, one obtains:

$$\kappa \frac{dT_e}{dx} = \left(\frac{1}{2} kT_e + \psi - \phi_C \right) \Gamma_e \quad (3)$$

where ϕ_C is usually greater than the sum of $1/2 kT_e + \psi$. Therefore, the derivative of electron temperature should be negative.

Furthermore, if Equation (1) is differentiated and the higher order terms are neglected, one obtains:

$$\frac{dU_e}{dx} = \left(\frac{5}{2} kT_e + \psi \right) \frac{d\Gamma_e}{dx} + \frac{5}{2} kT_e \frac{dT_e}{dx} + e \frac{d\psi}{dx} \quad (4)$$

Combining the above equation with the differential equation of electron energy flux in the plasma,

$$\frac{dU_e}{dx} = -(V_i + \psi) \frac{d\Gamma_e}{dx} \quad (5)$$

One obtains:

$$\frac{5}{2} kT_e \frac{d\Gamma_e}{dx} + \Gamma_e \frac{d\psi}{dx} = -(\frac{5}{2} kT_e + V_i + 2\psi) \frac{d\Gamma_e}{dx} \quad (6)$$

The results of the calculation indicate that the right hand side of the above equation is negative and the derivative of potential, ψ , is positive as it approaches the collector; this infers that the derivative of the electron temperature should be negative.

Both of the foregoing analyses indicate that the derivative of electron temperature should not be positive as it approaches the collector, which is contradicted by the results of the computer model. The reason for this inconsistency is not clear. Recently, an attempt has been made to solve the system of plasma differential equations by the finite difference method. The difference in approach between the finite difference method and the step-by-step numerical integration scheme can be characterized as the difference between solving the problem in "parallel" or in "series." In the step-by-step numerical integration technique, the solution at

one point is determined by the solution at another point. Thus the solution at the points near the far electrode are determined with less accuracy than that at the points next to the near electrode because of the propagation of round-off errors. Hopefully, the finite difference method will yield more stable solutions than the step-by-step numerical technique.

II. LOW TEMPERATURE CONVERTER DEVELOPMENT

A. CONVERTER NO. 209: TUNGSTEN EMITTER, LANTHANUM HEXABORIDE COLLECTOR

Unxygenated power output data for this converter (see Figure 8) were presented in Progress Report No. 37. Oxygenation of the converter was attempted by introduction of measured amounts of oxygen into the showerhead tubulation behind the collector.

Initially, oxygen at pressure of 5 torr was introduced into the tubulation for 24 hours. The diode conditions were $T_E = 1200$ K, $T_C = 600$ K and $T_R = 422$ K. The collector work function was monitored by the retarding plot method. Prior to oxygen admission, $\phi_C = 1.60$ eV. After 24 hours of oxygen exposure, $\phi_C = 1.69$ eV. The oxygen was pumped out of the tubulation and power data

Figure 8. LaB_6 "Showerhead" Collector Converter.

power data were taken at $T_E = 1400$ K. A comparison of J-V characteristics before and after oxygenation (at $T_E = 1400$ K, $T_C = 850$ K, $T_R = 551$ K) is shown in Figure 9. Two differences are evident; the "knee" of the curve has increased from 5 to 8 A/cm², and the barrier index has increased approximately 0.2 eV. The collector work function was again measured by the retarding plot method and was also found to be approximately 0.2 eV higher than its original value of 1.69 eV immediately after exposure to oxygen.

It was concluded that some oxygen had diffused through the showerhead collector into the converter - indicated by higher emitter currents - and that an oxide layer had formed on the collector - indicated by the rise in collector work function. A high-pressure (10 torr) cesium "soak" was applied for 24 hours (at the conditions $T_E = 1500$ K and $T_C = 850$ K) in an attempt to clean the LaB₆ surface. An uneven ignition was observed between the electrodes. Initial retarding plot measurements after the "soak" still showed a high collector work function. However, subsequent power curves ($T_E = 1400$ K) showed a drop in emitter current (at the "knee") back to 5 A/cm² and a return of the barrier index to close

Figure 9. Comparison of I-V Characteristics Before and After Oxygenation.

to its original value. Repeated retarding plot measurements also showed a return in the collector work function to close to its original value of 1.69 eV immediately after oxygen introduction. These series of steps indicate that the cesium soak did clean the collector surface. Unfortunately, the positive effects of oxygen on the emitter were also lost.

Attempts to oxygenate the converter again failed. Oxygen was introduced into the showerhead tubulation at pressures of 5, 10, 20, 40, 80, 150 and 300 torr for periods of 4 hours. No changes in converter characteristics were noted. It was suspected that oxygen could no longer diffuse through the LaB_6 because of an occlusion, possibly caused by the formation of lanthanum oxide or cesium oxide in the pores of the sintered LaB_6 collector. Attempts to heat the collector and unclog the LaB_6 were unsuccessful (the collector could not be heated above 950 K). The development of a leak in the collector-ceramic seal ended the experiment.

The diode was cut open and examined. The collector was oxidized, and small cracks were apparent on the surface.

B. CONVERTER NO. 207: TUNGSTEN EMITTER, TUNGSTEN OXIDE COLLECTOR

After 1550 hours of operation, Converter No. 207 still showed evidence of an electrically resistive layer on the collector surface. Subsequently, the diode was subjected to 10 torr of cesium for 24 hours ($T_c = 850$ K). After three such cesium "soaks", the collector exhibited normal tungsten oxide operation in the pre-activation state. Performance was further enhanced by heating the collector to 850 K for several 10-minute periods. Output characteristics were measured at a collector temperature of 750 K and emitter temperatures of 1450, 1560, and 1830 K over a range of interelectrode spacings. The non-standard emitter temperatures were due to a faulty thermocouple reading. The cesium-optimized performance at several interelectrode spacings for these emitter temperatures are given in Figures 10 through 13. At 4 A/cm^2 the barrier indices were 2.02, 2.02, 2.03 and 2.05 eV at emitter temperatures of 1450, 1560, 1670 and 1830 K, respectively.

After operating for approximately 300 hours at the above outputs, the converter performance degraded - signaling that the diode was now in the post-activation

Figure 10. Optimized Converter Performance at Various Spacings, $T_E = 1450 \text{ K}$.

Figure 11. Optimized Converter Performance at Various Spacings, $T_E = 1560 \text{ K}$.

Figure 12. Optimized Converter Performance at Various Spacings, $T_E = 1670$ K.

Figure 13. Optimized Converter Performance at Various Spacings, $T_E = 1830$ K.

period. Presently, the barrier index is 2.09 eV at $T_C = 750$ K, $T_R = 528$ K and $d = 0.5$ mm. Testing will continue on this diode.

III. ENHANCED MODE CONVERTER EXPERIMENTS

The triode converter experiment was terminated due to a window leak in the final stage of testing. A topical report summarizing the triode converter test data is being drafted.

IV. COMPONENT HARDWARE DEVELOPMENT

A. ALLOY HOT SHELL DEVELOPMENT

Negotiations have begun with TRW for a subcontract effort on hot shell materials. It is anticipated that this effort will include evaluation of candidate alloys, development of barrier coatings and simulated flyash erosion tests.

B. CVD HOT SHELL-EMITTER DEVELOPMENT

Efforts were continued on identifying leaks and determining their location on each composite hot shell. A leak tight composite hot shell was successfully copper brazed to a molybdenum flange. However, a leak developed in the shell when the flange was machined.

Both silicon carbide and composite hot shells were leak checked and found to be porous at the dome. The silicon carbide deposit on the dome (which is usually shiny and black) was permeable to helium during the "sniffer" and helium soak leak tests. However, the base and open end of the silicon carbide deposit were leak tight. The temperature profile of the graphite shell prior to the start of the deposition showed that the nose was 60 to 80 C colder than the base. Attempts to obtain a more even temperature profile from the dome to base by changing the RF coil configuration were not successful.

Five silicon carbide chamber designs were set up and compared in order to achieve a uniform temperature from the dome to the open end of the graphite shell (see Figure 14 and Table III). Two of these, the RF concentrator and venturi chamber, allowed the RF power to be concentrated onto the dome of the graphite shell and resulted in a uniform temperature. Silicon carbide deposits made with these two furnace designs produced leak tight hot shells.

Attempts were made to braze four leak tight shells to molybdenum flanges. The first step in the procedure is to machine the open end of the composite hot shell.

A
STANDARD SiC CHAMBER

B
GRAPHITE RADIATOR

C
HOT WALL CHAMBER

D
VENTURI CHAMBER

E
R.F. CONCENTRATOR

Figure 14. SiC Chamber Designs.

TABLE III
FURNACE DESIGN EVALUATION

<u>DESIGN</u>	<u>TEMPERATURE PROFILE</u>	<u>SILICON CARBIDE CVD RESULTS</u>
Standard Chamber	1250 + 40 C Dome $\bar{60}$ - 80 C Colder Than Base of Graphite Shell	Black-Shiny Deposit on Hemispherical end
Graphite Radiator	1250 + 30 C Dome $\bar{40}$ - 60 C Colder Than Base of Graphite Shell	Dome Deposit Very Thin Not Leak Tight
Hot Wall Chamber	1100 + 10 C Uniform Temperature	Inadequate R.F. Power Available for Deposition Temperatures of 1250 C
Venturi Chamber	1250 + 10 C Uniform Temperature	Thick Deposition at Dome Leak Tight Shell
R.F. Concentrator	1250 + 10 C Uniform Temperature	Uniform Deposition Thickness Leak Tight Shell

This is done for two reasons:

1. To expose a clean tungsten surface, free of any silicon carbide, which is necessary for a leak tight copper braze.
2. To enable the hot shell to be properly aligned relative to the flange and collector.

Three of the four shells developed leaks at the open end during machining. Although the remaining one was successfully brazed, a leak developed after its molybdenum flange was machined.

In order to avoid any machining of the brittle interface of the tungsten and silicon carbide, two improvements to the procedure were implemented:

1. A graphite gasket is used during the silicon carbide deposition, which keeps the inside surface of the tungsten clean.
2. Any misalignment between the flange and the hot shell will be compensated for during the last stages of converter assembly.

As a result of these changes, successful copper braze joints have been made without any machining of the composite hot shells.

C. SUBASSEMBLY DEVELOPMENT: INTEGRAL CESIUM RESERVOIR
CONVERTER NO. 208: TUNGSTEN EMITTER, NICKEL
COLLECTOR, CESIUM-GRAPHITE RESERVOIR

The performance of this converter was described in the report for the last period. It was found that a suitable cesium reservoir was formed with the graphite when the excess liquid cesium in the usual reservoir was pinched off. The operating temperature of the new reservoir was close to the value at which the cesium was soaked into the graphite. The new reservoir gave a pressure-temperature curve similar to that for liquid cesium, but shifted approximately 190 K higher in temperature.

After testing for about 300 hours, the converter was taken off the test stand and prepared for mounting in a life-test station. Considerable difficulty was encountered when arranging the support structure and the bell jar to fit the graphite reservoir as it projected beyond the usual converter mounting diameter. The tubulation to the reservoir had to be bent to a sharper angle so that it would fit. Apparently, a small leak developed during this procedure. Initial tests after transfer to the life-test station showed evidence of a leak since the performance was poor and the reservoir operating temperature for best operation was about 970 K rather than the 750 K before moving the converter.

V. SYSTEM STUDIES

Stone and Webster Engineering Corporation has completed their preliminary study of a thermionic-topped central station powerplant fired with coal. The preparation of a topical report summarizing the study has begun.

VI. TAM MODULE DEVELOPMENT

A. CONVERTER NO. 213: PROTOTYPE DEVICE NO. 2

The design of this diode was described in Progress Report No. 37. Construction was completed and the converter was outgassed. Considerable gas evolution was observed, particularly at emitter temperatures above 1400 K. However, tests proved negative.

The diode performance was poor (V_B range from 2.2 to 2.4 eV). Higher than normal interelectrode heat flux, slow response to cesium reservoir temperature, and the slope of the I-V curves indicated gas accumulation in the converter. Testing was terminated. At room temperature, the emitter and collector were shorted.

Examination of the opened converter indicated some deformation of the top of the emitter dome. No leaks were detectable, but the quantity of the active cesium remaining in the converter was minute.

The direct gas cooling of the collector and emitter flanges functioned well, and the insulator shield kept emitter evaporation from reaching the ceramic. The maximum short term testing temperature for this design is 1500 K.

B. CONVERTER NO. 218: SILICON CARBIDE CONVERTER NO. 1

A flame-heated diode using a composite CVD hot shell-emitter has been designed. Construction of this converter has begun.

PART TWO: JPL TASKS

I. HIGH-TEMPERATURE CONVERTER EVALUATION

A. CONVERTER NO. 210: TUNGSTEN EMITTER, MOLYBDENUM
OXIDE CONVERTER

Converter NO. 210 was disassembled during this reporting period. Visual inspection revealed growths on the molybdenum oxide collector. These growths were probably responsible for the electrical shorting noticed during testing. A number of postoperational diagnostics, including Auger electron spectroscopy and photomicrographs, will be performed on the collector.

B. CONVERTER NO. 212: MOLYBDENUM-RHENIUM HYBRID

The construction of this converter is identical with Converter No. 202. Converter performance was measured at emitter temperatures 1500, 1600 and 1700 K. The barrier index, when optimized, was 2.10 eV at 1500 K. The work function measured by retarding plots is shown in Figure 15. The minimum work function is 1.64 eV.

The hybrid converter, with a 2.1 eV barrier index produced a maximum output power density of 1.2 W/cm^2 at an emitter temperature of 1500 K. At the same emitter temperature, Shimada reported⁽⁵⁾ a power density of 0.95 W/cm^2 with a barrier index of 1.96 eV. Based on

Figure 15. Collector Work Function Versus the Ratio of Collector Temperature to Cesium Reservoir Temperature.

the observations of the discharge and the shape of the current-voltage characteristics, it is believed that the Thermo Electron hybrid converter configuration always operated in a conventional ignited mode. Attempts to obtain the hybrid mode condition by increasing the inter-electrode spacing resulted in worse performance in all cases.

Subsequent to these performance measurements, spectroscopic determinations of plasma density and electron temperature were taken on this converter. These data are discussed in Section I-B, Part One of this report.

C. CONVERTER NO. 216: TUNGSTEN EMITTER, MOLYBDENUM OXIDE COLLECTOR

Converter No. 216 is identical in construction with Converter No. 210. An 0.14-mm thick coating on a niobium substrate was formed in the presence of 7.5×10^{-5} torr of oxygen to form the collector. An identical substrate, prepared in a similiar manner, contained 4700 ppm of oxygen by weight. Performance of this converter will be compared to the performance of Converter No. 210, whose collector contained 3200 ppm of oxygen by weight. This converter has been outgassed and performance testing has begun.

II. ADVANCED CONVERTER STUDIES

Activation tests on single electrodes coated with RCA "barium oxide" (a composition of barium, strontium and calcium oxides) were completed. These tests were performed in a high-vacuum ion pump system. Barium oxide deposited on molybdenum electrodes, which have been used in previous particle spaced tests, has been quite difficult to activate. Work functions ranged about 0.2 eV higher than expected for activated barium oxide. An electrode of 201 nickel coated with barium oxide proved much easier to activate, requiring only one heating cycle to 1050 C. Work function values were also lower than those associated with a molybdenum substrate. "RCA nickel" electrodes coated with barium oxide were also easily activated and gave slightly lower work functions than the 201 nickel electrodes.

A particle-spaced diode experiment is being set up utilizing the results of the single electrode tests. Two "RCA nickel" electrodes have been sprayed with approximately 1/2-mil coatings of barium oxide. The two coatings will be placed in contact, and both electrodes will be simultaneously heated by electron bombardment to 1050 C. This will insure proper activation temperature for both the emitter and collector surfaces. This

experiment will be carried out in a high-vacuum ion pump system.

Construction of the cesiated particle thermionic converter is continuing. This converter should be tested during the next reporting period.

III. POST OPERATIONAL DIAGNOSTICS

No postoperational diagnostics were performed on any JPL converters during this period.

IV. CYLINDRICAL CONVERTER COMPONENT DEVELOPMENT

A literature survey on high-temperature electrical insulation was begun. Recommended thermoelectric property data for the design of a "P" semiconductor lead were requested from Syncal Corporation. Specific hardware efforts will be initiated after the design interfaces are better established.

V. CORRELATION OF DESIGN INTERFACES

A coordination meeting was held at JPL on 27 March 1979 for the purpose of discussing the design of the thermionic converter used in the JPL system study. The meeting was attended by K. Shimada, J. Mondt, G. Stapfer and W. Phillips of JPL, and F. Huffman and G. Miskolczy

of Thermo Electron. JPL described the present baseline design of the thermionic energy conversion system, as shown in Figure 16. Each reactor heat pipe carries two thermionic converters. There are four layers of thermionic converters in the system, each arranged in a radial pattern. The two layers of heat pipes furthest from the reactor are heated by reactor heat pipes passing axially through the center of the nearest two layers of the converters. A separate collector heat pipe is connected to each converter, and leads to the outside of the spacecraft. The baseline system assumes that each thermionic converter, emitter, and collector is electrically isolated from the heat transfer systems. Four converters, arranged radially in each layer, are connected in parallel and each radial row is connected in series with the next radial row. Likewise, these converters are series-connected with subsequent layers.

The baseline dimensions for the thermionic converter used in the JPL study are shown in Figure 17. The effective ratio of the emitter is assumed to be 4:1. The emitter diameter is 40 mm, thus the emitter length is 160 mm. The wall thickness of the emitter and collector is assumed to be 3 mm. The thickness of the emitter and collector insulating layers are assumed to be 0.5 mm and 1 mm, respectively.

SST-7

MARCH 28, 1979

Figure 16. Baseline Design of Thermionic Reactor System
(JPL Illustration).

793-13

Figure 17. Thermionic Converter Dimensions Used In JPL Study.

Based on this meeting, the design of the cylindrical converter was redirected. The "half-length" converter described in Report Nos. 36 and 37, which has an emitter length of about 170 mm, is longer than the full length converter shown in Figure 13. During this reporting period, the design effort was directed to a full-length converter with the dimensions shown in this figure.

BLANK

REFERENCES

1. E.K. Storms and B. Mueller, "A Study of Surface Stoichiometry and Thermionic Emission Using LaB_6 ," submitted to J. Phys. Chem.
2. DOE/JPL Advance Thermionic Technology Program, Progress Report No. 37, Thermo Electron Corp. Report No. TE 4258/4247-132-79.
3. D. Lieb and W. Bornhorst, "Analysis of the Diffusion Dominated Thermionic Converter Plasma," Proc. Thermionic Conversion Specialist Conf., p. 191, Oct. 30 - Nov. 1, 1967, Palo Alto, Calif., .
4. C.C. Wang, "Topical Report: Numerical Solution of the Thermionic Diode Plasma Equation with the Electron Temperature as a Function of Position," Thermo Electron Corp. Report No. TE 4237-148-78, April 1978.
5. K. Shimada, "Low Arc Drop Hybrid Mode Thermionic Converter," Proc. 12th Intersociety Energy Conversion Engineering Conf., p. 1568 (1977), .