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DESIGN AND CONSTRUCTION FEATURES OF A
VARIABLE GAP THERMIONIC CONVERTER TUBE

Livermore, California

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THERMIONIC CONVERTER TUBE

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ABSTRACT

Design and construction features are presented for a parallel-plane thermionic converter tube which has an interelectrode gap that may be precisely varied from zero to 6 inches.

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INTRODUCTION

Theoretical analysis¹ has indicated that highly efficient thermionic conversion of heat into electricity might be achieved by use of an interelectrode heat shield array combined with a magnetic field which would channel the emitted electronic current through the heat-shield region without serious losses. Installation of heat shields in the interelectrode gaps of ordinary vapor thermionic converters is not practical because of the close spacing involved, usually about 0.01 to 0.05 inch. If the current can be channeled for distances many times the above dimensions, then the use of heat shields become feasible and the radiant power losses of the converter may be substantially reduced.

In order to test the channeling hypothesis, a parallel-plane thermionic diode has been constructed. This diode has a guarded anode which may be precisely moved to provide interelectrode gaps varying from a few mils to 6 inches. This report records the design characteristics and intricate assembly details associated with its construction.

DESIGN REQUIREMENTS

In order to obtain precise measurements of current loss with increased interelectrode distance, the test device had to meet the following basic requirements.

- (a) It had to operate as a cesium vapor thermionic converter in order to duplicate the thermal conditions, space-charge barriers, and degree of plasma neutrality found in thermionic converters.

¹Raymond Fox, "Heat-Shielded Magnetically Channeled Plasma Heat Converter," UCRL-6553 (1961).

- (b) Parallel-plane guard-ring geometry was essential in order to obtain reliable current density measurements.
- (c) The radial dimensions had to be kept small so that the system could be immersed in a hot-oil bath which would control the temperature of the cesium reservoir and hence the cesium vapor pressure. Further, it was required that the oil bath and the immersed tube be placed in a solenoid to obtain the channeling magnetic field.
- (d) All components had to be of nonmagnetic materials.
- (e) The diode had to be capable of operating at ambient temperatures up to 350°C.

CONSTRUCTION

The diode is shown in Fig. 1. It was constructed in three separable subassemblies, the cathode heater, the cathode, and the anode sections. The main construction materials selected consist of tantalum, nonmagnetic stainless steel, copper, and Coors AD 96 alumina insulators. The tube was designed so that the insulators were brazed to either tantalum or copper parts because of the favorable relation of the thermal coefficients of expansion of those materials to that of the ceramic. Each subassembly was designed so that the parts would be self-jigging as much as possible, and so that the insulator brazes could be made last in order to protect the metallized ceramic from injurious thermal cycling. The insulators ended up being radially in compression in the final assembly so that small thermal growth simply relieves locked-in stresses.

The cathode is heated by electron bombardment, and requires about 500-watts power input to attain a cathode temperature of 2500°K. The heater subassembly and the various step-brazing and welding techniques used are shown in Fig. 2. Cathode temperature is measured by sighting through the sapphire window with an optical pyrometer. The window may be withdrawn from the path of back-bombarding electrons by flexing the window end of the bellows radially. The heater section operates in a continuously pumped vacuum.

The cathode subassembly and the step-brazing and welding techniques used on it are shown in Fig. 3. The disk at the end of a tube geometry was chosen in order to shield the anode from regions of high electron emission caused by cesium adsorption on the cooler portions of the cathode base. The

Fig. 1. Variable gap thermionic converter tube.

Fig. 2. Cathode heater subassembly.

Fig. 3. Cathode subassembly.

cathode was milled from a solid rod of tantalum and consists of a 3/4-inch-diameter disk 1/4-inch-thick located at the end of a tube 3-5/8 inches long. Conduction losses were reduced by making the supporting walls 0.007 in. thick in region adjacent to the disk. The circumference of the disk was knurled to provide sharp points where four 1-mil dimpled tantalum foils were attached for heat shielding and additional structural support. The heat shields were spot-welded to point contacts on the knurling to reduce thermal conduction.

To prevent radial thermal expansion from putting undue stress on the ceramic, the section at the base of the cathode was fluted circumferentially. This provided a stiff spring action to absorb the radial thermal growth of the cathode base. A strong vacuum-tight tantalum-to-copper weld joins the cathode base to the adjacent copper ring. This weld was made by flowing a thin layer of copper on the tantalum in a helium atmosphere. This was followed by copper-to-copper heliarc welding, also in helium. A circumferential cooling passage was located between the cathode base and the metal-to-ceramic braze. Additional cooling circuits could be installed externally.

The two small insulated feed-through pins located radially outward from the cathode are for Langmuir-type plasma probes.

The movable anode and the various step brazes involved in its construction are shown in Fig. 4. The anode, made of tantalum, is electrically insulated from its guard ring. The circular guard ring is composed of a 1/8-inch-thick tantalum ring brazed to a copper base. It is separated from the anode by a 5-mil circular gap. Passages for cooling fluid are provided for both the anode and guard ring.

The anode is centered and supported in the region near the cathode by three spring-loaded wheels located 120° apart. Coaxial support for the anode section is also provided at the lower end of the bellows where it is connected to a collar which slides on four rods which are rigidly anchored to the main tube envelope. Further coaxial support is provided by the jacking screw and nut which are also anchored to the same four rods.

Longitudinal motion of the anode is very smoothly accomplished by rotating the jacking nut, which transfers force from the anchored collar to the threaded section of the anode extension through radial-thrust ball bearings. Vacuum integrity is maintained by using a Belfab bellows which has a 6-1/2-inch total stroke.

Fig. 4. Anode subassembly.

Each of the subassemblies has been constructed and vacuum-leak checked. Work remaining to be done consists of:

- (a) Installation of the heater filament which should be a 10-mil-diameter tungsten wire spot-welded to the 60-mil-diameter tungsten support rods as shown in Fig. 2.
- (b) Installation of external cooling fluid circuits.
- (c) Design, construction, and installation of an external measuring system which would precisely determine the variable interelectrode gap length.

LRL drawing numbers for all parts in the assembly are listed in Fig.

5.

Thermionic conversion effort at LRL was terminated prior to operation of this tube. It has been placed in storage and is available for use if adaptable to some other experimental program.

/mr

ITEM	PART NO.	DESCRIPTION	NO. REQ'D
1	62-117748	SAPPHIRE WINDOW ASSEMBLY	1
2	62-117747	SAPPHIRE WINDOW SUPPORT	1
3	62-117744	BELLOWS SUPPORT	1
4	62-117739	CAP	2
5	62-117736	FILAMENT LEAD THRU	1
6	62-117732	UPPER CONOSEAL ADAPTOR	1
7	62-117758	UPPER CATHODE CONNECTOR	1
8	62-117729	UPPER CERAMIC CONNECTOR	1
9	62-118001	CATHODE CONNECTOR	1
10	62-118002	CATHODE	1
11	62-117753	CONNECTOR	1
12	62-118006	LEAD THRU CAP	2
13	62-118007	FLANGED RING	1
14	62-118010	HOUSING	1
15	62-118011	FLANGE	1
16	62-118013	FLANGE	1
17	62-117777	ANODE ARM	1
18	62-117782	SUB ASSEMBLY	1
19	62-118014	GUARD RING	1
20	62-118015	GUARD RING TOP	1
21	62-118019	SLEEVE	1
22	62-118021	ANODE	1
23	62-118023	FLANGE	1
24	62-117766	THREADED SHAFT	1
25	62-117760	ADJUSTING NUT	1
26	62-117774	NUT	1
27	62-117770	BEARING BRACKET	2
28	62-117765	STRUT	2

Fig. 5. Bill of materials.

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