APR 3 1962

MASTER

UNCLASSIFIED

AD 264135 ✓

*Reproduced
by the*

ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA

UNCLASSIFIED

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.

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

CATALOGED BY ASTIA
AS AD No. 264135

ASTIA
RECEIVED
OCT 12 1961
RESERVED
TIPDR

REPUBLIC
AVIATION CORPORATION

61-4-6
XEROX

First Progress Report

RESEARCH ON THE EFFECTS
OF MAGNETIC FIELDS
ON THERMIONIC POWER GENERATION

RAC 458

Prepared for

OFFICE OF NAVAL RESEARCH
Contract No. Nonr-3285(00)

by

Alfred Schock
A. Schock
Chief Investigator

A. E. Kunen
A. E. Kunen
Manager

Plasma Propulsion Laboratory
REPUBLIC AVIATION CORPORATION
Farmingdale, L. I., N. Y.

INTRODUCTION

Republic Aviation Corporation is engaged in a theoretical and experimental study of magneto-thermionic power generators. This concept promises a number of advantages over conventional thermionic generators.

As shown in an earlier report entitled "Effect of Magnetic Fields on Thermionic Power Generators", low pressure cesium diodes suffer from an undesirable size limitation, because self-induced magnetic fields reduce current transmission and hence, efficiency. Although this effect does not arise in the small devices tested to date, it becomes important in building larger generators. Analysis indicates that this problem can be virtually eliminated by the application of a longitudinal magnetic field.

To verify the predicted magnetic field effects, and to examine their possible use in AC generation, we are engaged in an experimental and theoretical study, the current status of which is described in the attached progress report.

* A. Schock, J. Appl. Phys. 31, 1978 (1960).

PROGRESS REPORT, CONTRACT Nonr-3285(00)

The special requirements of our program have imposed a number of difficult constraints on the design of the experimental apparatus. First, in order to measure the effect of magnetic fields, the test cell (including its temperature control oil bath) must be compact enough for insertion between the pole faces of an electromagnet. By adjusting the magnet's field strength and the orientation of the test cell with respect to the field lines, we are able to simulate any combination of longitudinal and transverse fields (see Figure 1).

Figure 1 - Magneto-Thermionic Test Rig

In the second place, it is imperative that the angle between the magnetic field lines and the emitter surface be well defined. Consequently, we must employ planar rather than cylindrical electrodes. Moreover, the electrodes must be fairly large, in order to minimize edge effects. For this reason, 3 inch diameter disk electrodes (45 cm^2) were chosen.

Finally, it appears inadvisable to heat the cathode by means of electron bombardment, since the magnetic field tends to deflect the electron heating beam, thus causing a non-uniform temperature distribution.

The above constraints have resulted in a number of vexatious problems, the solutions of which have demanded a great deal of time and effort. As depicted in Figure 2, the heating element consists of a coiled tungsten filament and a beryllium oxide support plate. Heat

Figure 2 - Cathode Heating Element

transfer to the cathode is by conduction as well as radiation. Figure 3 shows a heating test in which a 3 inch diameter disk was heated in an evacuated bell jar to a temperature of 1900°K. As far as could be detected by optical and pyrometric observation, the cathode temperature was quite uniform. It is anticipated that substantially higher temperatures will be achieved in the closed diode.

After resolving the heating problem, the design and construction of the actual test cells was tackled in two stages. The first test cell, shown in Figure 4, has a copper housing, fixed electrode spacing, and no separation between the two sides of the emitter. Consequently, the tungsten heating element is immersed in the same cesium atmosphere as the electrode gap, a condition which may lead to some ambiguity in interpreting the results. The diode design provides for interchangeable

Figure 3 - Cathode Heating Test

Figure 4 - First Test Cell

cathodes (bare tungsten, thorium impregnated tungsten, and tungsten impregnated with mixed alkaline earth oxides). Since the copper housing also acts as the collector, the temperature of the anode cannot differ greatly from that of the cesium reservoir. The completion of this diode has been delayed by problems with vacuum seals, electrical feed-throughs, and cathode leads capable of handling the strong currents resulting from the large electrode size.

The second phase of our diode program involves the design and construction of a more advanced cell, a cross-section of which is shown by Figure 5. This cell incorporates the following improvements over the earlier diode:

Figure 5 - Cross-Section of Advanced Test Cell

1. The stainless steel housing includes feed-throughs, valves, and adjustment screws, to permit variation of the electric field strength.
2. The cathode consists of a cylindrical plate of tungsten, mounted in a cup, which acts as a vacuum seal between the two sides of the housing. As a result, the cesium vapor pressure is maintained at a constant value, independent of the anode temperature.
3. The anode is a hollow disk, internally cooled by a circulating fluid. Consequently, the cesium pressure need not depend on the anode temperature, since the latter can be much hotter than the cell housing, if desired.
4. The cathode is grounded to the cell housing by means of the cathode cup. This eliminates the problem of attaching thin leads to the hot cathode.
5. The anode is electrically insulated from the housing by means of hollow feed-throughs, which act as coolant ducts.

Most of the components of the advanced cell have been completed (see Figure 6), and assembly will be started in the near future. A view of the complete test rig, including the electron spectrometer and the oil system for controlling the cesium pressure is shown in Figure 7.

Concurrently with the experimental program outlined above, we have been studying the possibility of turning the magnetic field effects to our advantage. Thermionic converters have an output on the order of 1 volt. Consequently, large power generators produce extremely high currents, unless a very great number of small cells is connected in series. The latter scheme entails the serious disadvantage of poor reliability, since failure of one cell may shut down the entire series. In our view, it is preferable to have a moderate number of large diodes, provided means exist for rapidly converting the low voltage, high current produced to the high voltage, small current demanded by the load. To do so by means of static inverters would be very difficult, since it would require a great many vacuum tubes to handle a total current on the order of 10^4 to 10^5 amperes. However, a thermionic converter is itself a gigantic vacuum tube, the output of which may be modulated by

Figure 6a - Advanced Test Cell Assembly

Figure 6b - Exploded view of Advanced Test Cell, showing anode a, bellows b, and cathode c

Figure 7 - View of Complete Test Rig Including Magnet and Temperature Control System

means of a periodically varying magnetic field. If the resultant current is passed through the primary of a suitable transformer, its AC component can be extracted and stepped up in voltage to meet the load requirements.

The above scheme, though attractive, must necessarily entail some sacrifice in efficiency. To assess the magnitude of this sacrifice, a comprehensive analysis of DC converters had to be carried out first, the results of which are presented in a report entitled "Optimization of Emission-Limited Thermionic Generator"* . This shows that for a given anode work function and cathode temperature, optimization of the

* A. Schock, J. Appl. Phys., 32, 1564 (1961)

other parameters leads to a decrease in the maximum conversion efficiency in terms of the fundamental physical constants e , m , c , and k . After completion of the DC analysis, a completely analogous study of the AC operation was carried out. It was found that the very simple mode of operation described above leads to very poor efficiencies. However, as has been reported elsewhere¹ in the near future, the system's performance can be greatly improved by employing a somewhat more complicated mode of operation. For a given anode work function and cathode temperature, the maximum attainable AC efficiency is equal to approximately 70 to 75% of the maximum possible DC value. It thus seems a reasonable price for the direct (static) generation of a high voltage alternating current.

DISSEMINATION DATA

<u>AGENCY</u>	<u>Copies</u>
Power Branch (Code 429) Office of Naval Research Washington 25, D. C.	2
Office of Naval Research Branch Office 346 Broadway New York 13, N. Y.	1
U. S. Naval Research Laboratory Technical Information Division Washington 25, D. C.	6
Naval Research Laboratory Code 6430 Washington 25, D. C.	1
Commanding Officer Office of Naval Research Branch Office Box 39 Navy #100 Fleet Post Office New York, N. Y.	2
Office of Technical Services Department of Commerce Washington 25, D. C.	1
Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia	10
National Aeronautics and Space Administration 1512 H Street Washington 25, D. C. Attention: James J. Lynch	1
National Aeronautics and Space Administration Lewis Research Center 2100 Brookpark Road Cleveland 25, Ohio Attention: Frank Rom Roland Breitwieser Bernard Lubarsky	3
Chief, Bureau of Ships Department of the Navy Washington 25, D. C. Attention: Code 342B Code 1500, LCDR J. H. Weber	2

AGENCY

Chief of Naval Operations (OP-07G) Department of the Navy Washington 25, D. C.	1
Division of Reactor Development U. S. Atomic Energy Commission Washington 25, D. C. Attention: Lt. Col. G. M. Anderson Doyle Rauch	2
Aeronautical Systems Division (ASRMFP-2) Wright Patterson Air Force Base Ohio	2
Air Force Cambridge Research Center (CRZAP) L. G. Hanscom Field Bedford, Massachusetts	1
Power Information Center (SP-01) University of Pennsylvania Moore School Building 200 South 33rd Street Philadelphia 4, Pennsylvania	1
Mr. A. F. Underwood Manager, General Motors Research Laboratories 12 Mile and Mound Road Warren, Michigan Attention: Dr. F. Jamerson	1
Atomics International P. O. Box 309 Canoga Park, California Attention: Dr. N. S. Rasor	1
General Atomic P. O. Box 608 San Diego 12, California Attention: Dr. R. W. Pidd Dr. R. C. Howard	2
Republic Aviation Corporation Farmingdale, Long Island, New York Attention: A. Schock	1
Director of Special Projects (SP-001) Department of the Navy Washington 25, D. C.	1

<u>AGENCY</u>	<u>Copies</u>
North Carolina State College Raleigh, North Carolina Attention: Dr. A. C. Menius	1
Allied Research Associates, Inc. 43 Leon St. Boston 15, Massachusetts Attention: Dr. P. Goodman	1
Ford Instrument Company 3110 Thomas Avenue Long Island City, N. Y. Attention: T. Jarvis	1
Armour Research Foundation 10 W. 35th St. Chicago 16, Illinois Attention: Dr. D. W. Levinson	1
Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena, California	1
RCA Laboratories David Sarnoff Research Center Princeton, New Jersey Attention: Dr. L. S. Negaard	1
Los Alamos Scientific Laboratory P. O. Box 1663 Los Alamos, New Mexico Attention: Dr. George M. Grover	1
Thermo Electron Engineering Corporation 85 First Avenue Waltham 54, Massachusetts Attention: Dr. George N. Hatsopolus	1
The Martin Corporation Baltimore 3, Maryland Attention: D. N. Tolat	1
Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois Attention: Aaron J. Ulrich	1

<u>AGENCY</u>	<u>No. of Copies</u>
Hughes Research Laboratories 3011 Malibu Cannon Road Malibu, California Attention: Dr. R. C. Knechtli	1
Thomson Ramo Wooldridge, Inc. 7209 Platt Avenue Cleveland 4, Ohio Attention: Wm. J. Leovic	1
General Electric Research Laboratory Schenectady, New York Attention: Dr. V. C. Wilson	1
Westinghouse Electric Co. Research Laboratories Beulah Road Churchillboro Pittsburgh, Pennsylvania Attention: Dr. Max Gavbuny	1
The Marquardt Corporation ASTRO Division 16555 Saticoy Street Van Nuys, California Attention: A. N. Thomas	1
General Telephone & Electronics Labs., Inc. Bayside 60, New York Attention: R. Steinitz	1
Advanced Research Projects Agency Washington 25, D. C. Attention: Dr. John Huth	1