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# Development of

# HIGH-TEMPERATURE, HIGH-CURRENT, ALKALI-METAL, VAPOR-FILLED CERAMIC THYRATRONS AND RECTIFIERS

by

A. W. Coolidge



prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Schenectady, New York 12305

TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

Development of

# HIGH-TEMPERATURE, HIGH-CURRENT, ALKALI-METAL VAPOR-FILLED CERAMIC THYRATRONS AND RECTIFIERS

by A. W. Coolidge
General Electric Company

## SUMMARY

The purpose of the National Aeronautics and Space Administration Contract NAS3-6005 is to advance the technology and to provide fundamental design data for high-temperature, high-current, alkali-metal, vapor-type ceramic tubes. The objectives of this program are to conduct a fundamental investigation of the problem areas associated with high-temperature, vapor-type tubes, and to fabricate and test prototype rectifiers and thyratrons to prove the technology and to provide application data for future reference. Phase I of this program is concerned with the investigation of the fundamental problems and the establishment of the conceptual design of prototype models.

During the reporting period, a diode was constructed with a thoriated-tungsten cathode and two tubes were constructed with barium-system cathodes and with thallium pellets.

# INTRODUCTION

A diode was constructed with a thoriated-tungsten cathode to test the feasibility of such a cathode in a tube where anode temperature up to 900$^{\circ}$C might be incurred. This tube was operated for more than 500 hours.

A thoriated cathode was designed for an average current capability of 7 amperes. In addition, a thyratron structure believed to be capable of an average current capability of 15 amperes was delineated.

Two thallium-filled devices were built. Mechanical problems have continued to plague these devices.

## PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

PUBLICATIONS - None

LECTURES - None

REPORTS

1. Monthly Progress Report No. 7
   Period Covered: 19 March 1965 through 18 April 1965
   Author: A. W. Coolidge

2. Monthly Progress Report No. 8
   Period Covered: 19 April 1965 through 18 May 1965
   Author: A. W. Coolidge

CONFERENCES

1. Organizations represented
   - National Aeronautics and Space Administration
     - E. A. Koutnik
     - R. L. Cummings
   - Missile Space Division, General Electric Company
     - R. Edwards
     - A. H. Powell
   - Microwave Tube Business Section, General Electric Company
     - E. A. Baum
     - A. W. Coolidge
     - N. D. Jones
     - D. L. Schaefer

   Place and date: General Electric Company, Schenectady, New York, April 5, 1965

   Subject: Review technical programs on this project

2. Organizations represented
   - National Aeronautics and Space Administration
     - E. A. Koutnik
     - H. A. Shumaker

Missile Space Division, General Electric Company

R. Edwards

Microwave Tube Business Section, General Electric Company

E. A. Baum

A. W. Coolidge

N. D. Jones

A. Michaelson

D. L Schaefer

Place and date: General Electric Company, Schenectady, New York, May 27, 1965

Subject: Review technical progress on this project.

## TECHNICAL DISCUSSION AND PROGRESS

### THORIATED-TUNGSTEN CATHODE

As a first step in the evaluation of thoriated tungsten, the Z-7009 tube 16 was constructed to determine feasibility. This tube contained a specially designed anode that fitted closely to a thoriated-tungsten cathode mounted on the bottom end of a type GL-6942 transmitting tube. The anode-cathode portion of the tube, less the bottom-end supports and seals, is shown schematically in Figure 1.

The tube was so designed that the anode temperature would be about 1000°C when the cathode was at the normal operating temperature of 1650°C. To avoid any compatibility problem that might arise from the use of one of the metallic-vapor fills, the tube was filled with 100 microns of xenon.

It was found initially that there was no inverse emission difficulty with an inverse anode voltage of 700 volts and an anode temperature of 1000°C. Because the anode might become more heavily coated with thorium later in life, but presumably never more heavily coated than the cathode surface itself, it was assumed that meaningful information might be derived from measuring forward breakdown as a function of cathode temperature. The lowest cathode temperature observed for forward breakdown (with 700 volts applied) was 950°C. Since this temperature is above the temperature at which electrodes must operate in a tube having a 600°C environment, it is felt that feasibility from the standpoint of temperature was demonstrated.

Initial emission curves for tube 16 are given in Figure 2.

While the tube was not made for life test purposes it was operated for 590 hours at an average current of 1 ampere. During this time, the cathode emission gradually dropped, until at the end of life the tube drop became excessive. Inverse anode emission characteristics were checked a number of times during this operation and at no time was there evidence of arc back with the anode temperature at 1000°C. No forward breakdown was observed unless the cathode temperature exceeded 900°C.

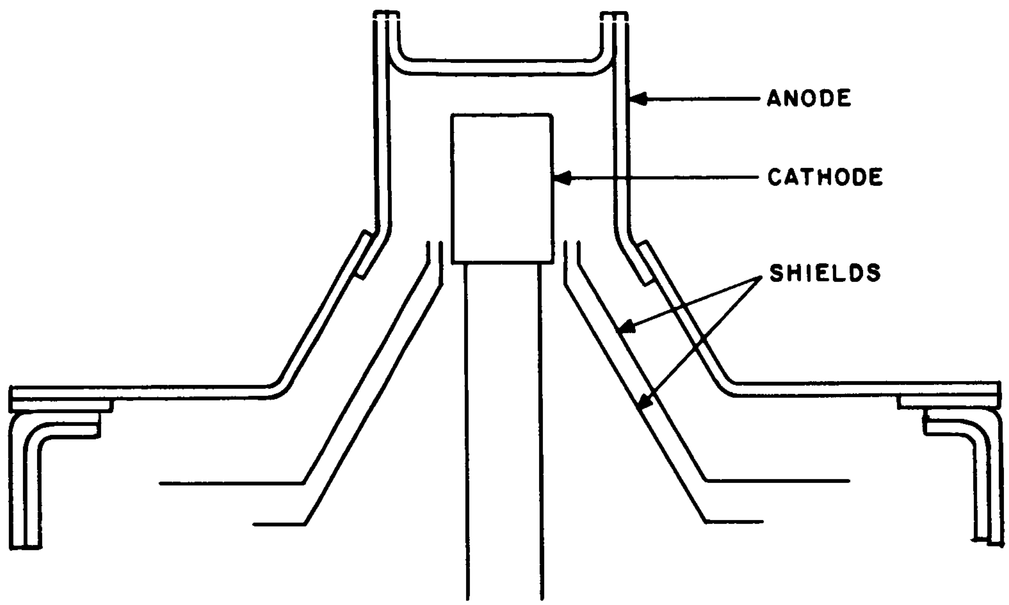


Figure 1 - Schematic of Test Vehicle, Design E

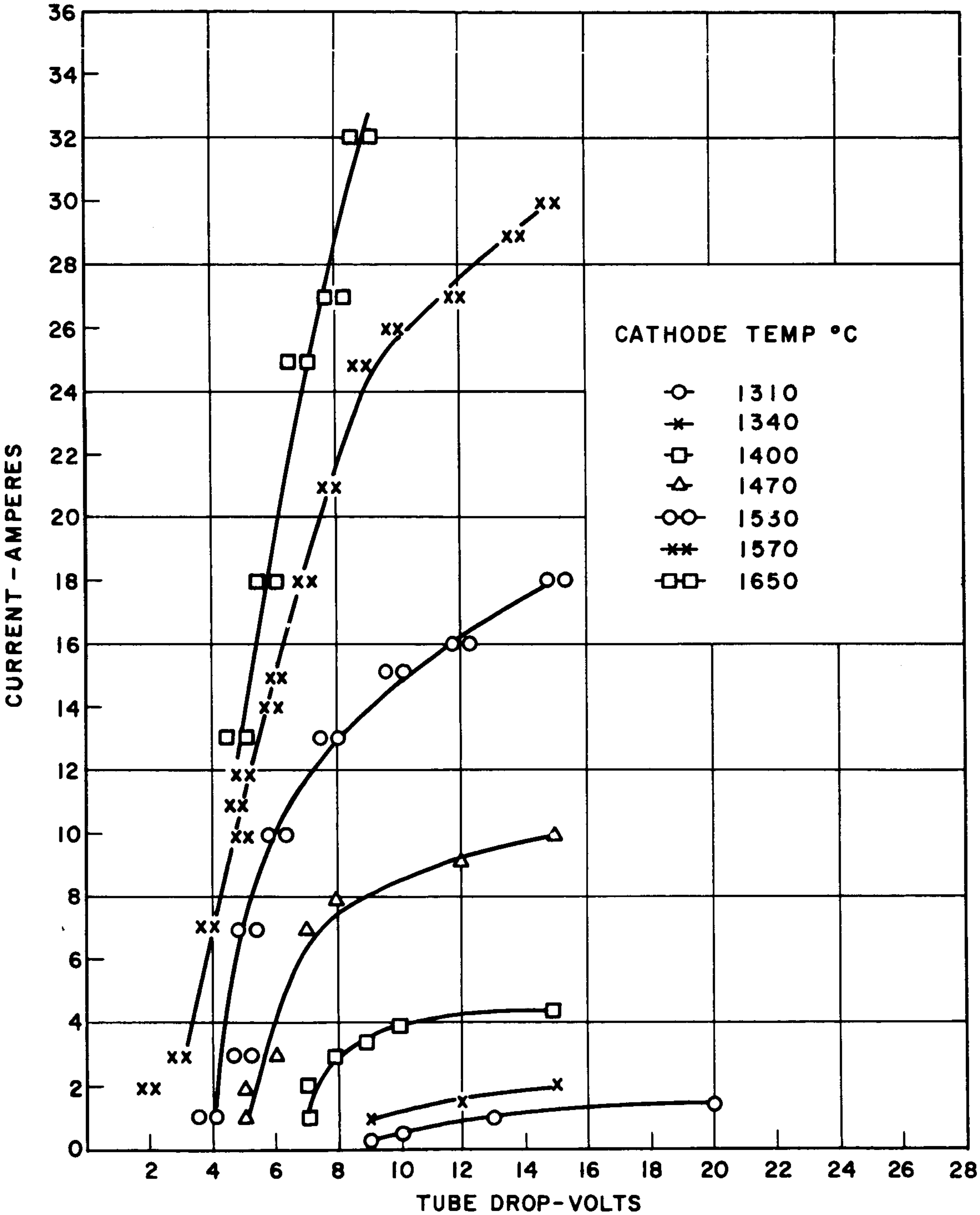


Figure 2 - Type Z-7009 Tube 16, Current vs. Voltage

Figure 3 depicts a thyratron structure capable of about 7 amperes average current. The thoriated-tungsten cathode is a filamentary design, spiral shaped and having about 10 square centimeters of area. A capacity of 15 amperes could be obtained by doubling the width of the thoriated-tungsten strip, providing an area of about 20 square centimeters. For a 15-ampere rating, the filament would operate at a voltage and current input of approximately 2.5 volts and 300 amperes, respectively. Although heat-sink details are not shown, the heavy disc construction should permit the efficient removal of heat from the interior of the tube to the heat sink.

## HIGH-TEMPERATURE VAPOR-FILL MATERIALS

Two more attempts were made to build a thallium-filled tube with a barium-system cathode. However, test data has been scanty and inconclusive because of structural troubles inherent in the test vehicles.

The Z-7009 tube 17 was made according to Design B, Figure 4, but without the shield that is in close proximity to the ceramic. By operating with a fill of xenon, cathode emission was checked on the exhaust system before pinch-off. Emission current appeared to be limited to about $\frac{1}{2}$ ampere maximum.

After exhaust and release of thallium from the pellet, the tube operated with a drop of 7 volts at a cathode temperature of $960^{\circ}C$. When cathode emission fell rapidly, however, it was necessary to raise the cathode temperature to $1200^{\circ}C$ and the anode voltage to several hundred volts in order to achieve forward conduction. Cathode emission improved with time and, after stabilization, tube drops of 3 to 9 volts were observed as the tube current was varied from 0.1 to 0.4 ampere. After about 1 hour of operation, tube conduction ceased. It was subsequently determined that the ceramic envelope had cracked, permitting the thallium to escape.

The Z-7009 tube 18 was made according to Design G, Figure 5. It featured wide welding flanges that would permit the tube to be taken apart a number of times for repair, inspection or replacement of parts. A ceramic and metal flange seal section was first assembled, Figure 6, to which the anode and cathode assemblies were welded.

This tube was exhausted and operated on the exhaust system with a xenon fill. With a cathode temperature of $1100^{\circ}C$, a tube drop of 10 volts was observed at a peak current of 5 amperes, a density of 1 ampere per square centimeter.

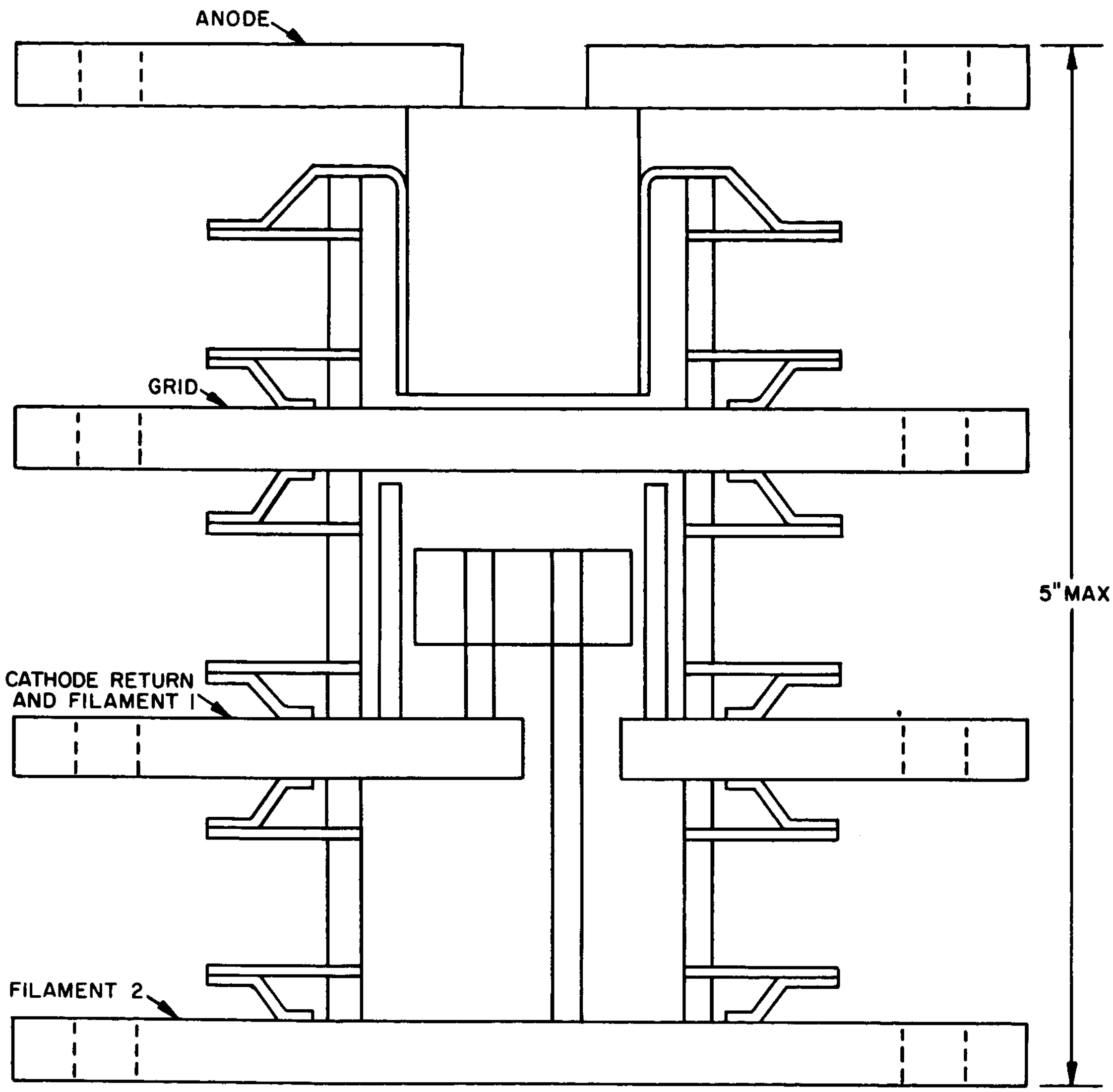

Figure 3 - Conceptual Design F for High-Temperature Thyratron

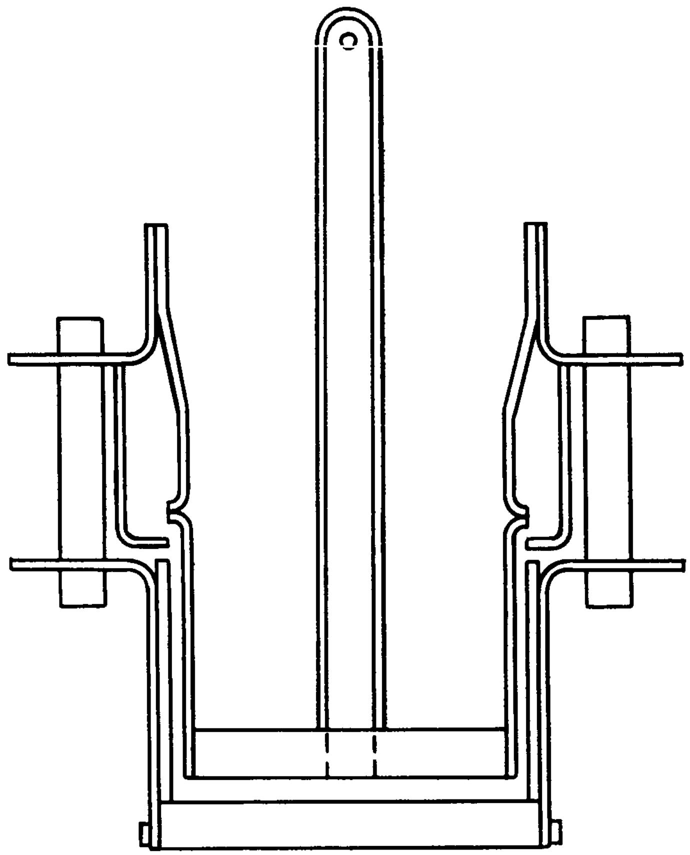

Figure 4 - Schematic of Test Vehicle, Design B

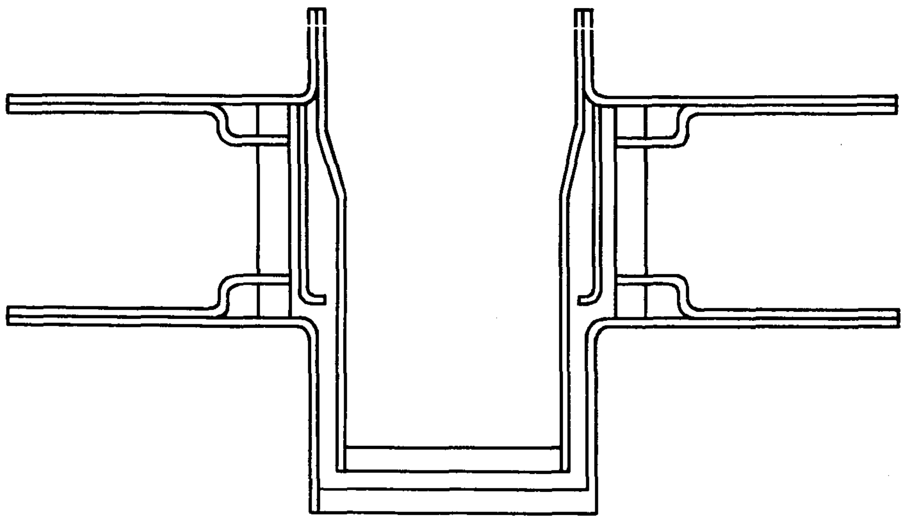

Figure 5 - Schematic of Test Vehicle, Design G

Figure 6 - Ceramic and Metal Flange Seal Section

After cooling and before pinch-off it was discovered that the tube had developed a leak. This leak was subsequently pin pointed at the molybdenum-to-tantalum weld where the cathode disc is joined to the cylindrical sidewall. The thallium pellet was never broken.

When rewelding failed to close the leak, the cathode assembly was removed by cutting away the weld at the outer edge of the cathode flange. A new cathode assembly was spot welded to the molybdenum flange preparatory to arc welding the flange joint. It was noticed, however, that the molybdenum flange had fractured at several of the spot welds. At this juncture it was decided to eliminate, insofar as possible, all joints involving welded molybdenum. Accordingly, anode and cathode assemblies were removed from the seal section (Figure 6) and the molybdenum flanges were cut back to small stubs that were just large enough to permit a brazed joint to be made to a tantalum flange extension. The tube was then reassembled as delineated in Figure 7. In subsequent devices, tantalum anode and cathode discs may be substituted for the molybdenum discs.

This rebuilt tube, designated 19, has been exhausted and is undergoing initial tests.

Another similar device, Z-7009 tube 12, is under construction and will be used for further evaluation of thallium or possibly bismuth.

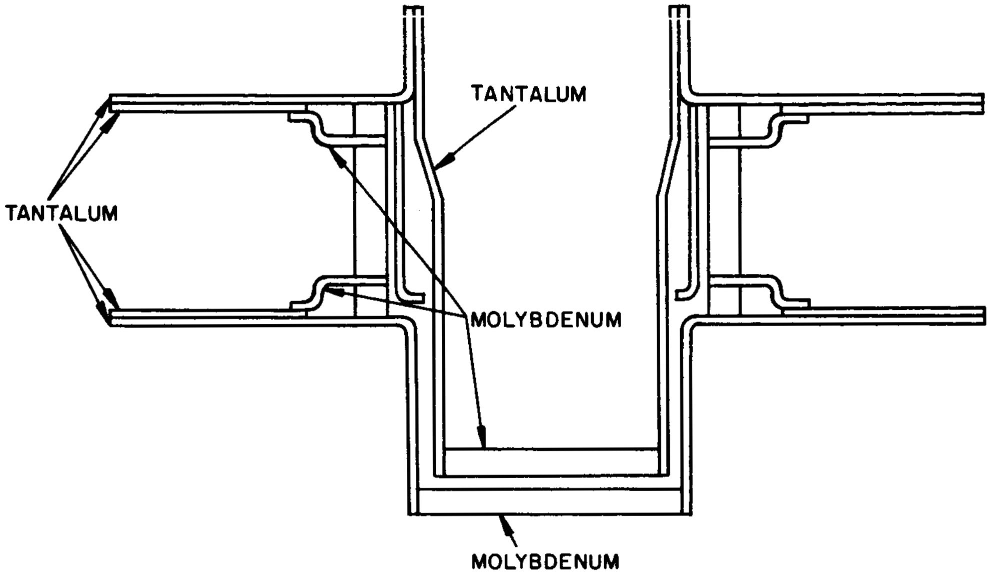


Figure 7 - Schematic of Test Vehicle, Design H

## PROGRAM FOR NEXT INTERVAL

During the next report period:

1. Thallium and bismuth will be evaluated in test diodes.
2. A thyratron will be constructed which will be capable of an average current of 7 amperes.

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## ABSTRACT

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A feasibility tube utilizing a thoriated-tungsten cathode was evaluated with respect to inverse emission.

A thyratron design with thoriated-tungsten cathode capable of 7 to 15 amperes average is described.

Further attempts at evaluating thallium as a vapor fill are described. Some design details of the test vehicles are given.