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Development of

HIGH-TEMPERATURE, GAS-FILLED, CERAMIC RECTIFIERS, THYRATRONS, AND VOLTAGE-REFERENCE TUBES

by

E. A. Baum

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS3-6469

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CONTRACT NAS3-6469
(Continuation of Contract NAS3-2548)

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Development of

HIGH-TEMPERATURE GAS-FILLED CERAMIC RECTIFIERS, THYRATRONS, AND VOLTAGE-REFERENCE TUBES

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SUMMARY

ABST 22355

Contract NAS3-6469 is a continuation of the work started under Contract NAS3-2548 for the development of high-temperature ceramic rectifiers, thyratrons and voltage-reference tubes for long term use in nuclear electric space power systems. The present phase of the program is directed at establishing the validity of the technology and design concepts.

An initial thyratron design has been completed and parts fabrication is in process. This design is based on the use of pyrolytic impregnated, porous graphite for the anode and grid materials. The present cathode being considered (and which will be used in the first series of tubes) is a porous sintered nickel cathode substrate impregnated with an emissive material and designed to operate at temperatures of 850°C to 900°C.

The purpose of this initial design is to establish the soundness of the interelectrode structure and materials concepts as well as optimum xenon loading pressure.

Parts fabrication and assembly of the voltage-reference tubes is in process. Five devices have been completed for initial test. Some difficulties were experienced during the final braze of the anode tubulation to the nickel support, resulting in a short circuit to the bottom of the molybdenum cathode cup. This has been corrected by adjusting the time cycle of the brazing procedure and the length of the tubulation.

Modifications of a new exhaust and gas loading system, which will provide exhaust and bakeout pressures of 5×10^{-8} torr, are nearly complete. This system will be used for processing both the thyratrons and the voltage-reference tubes.

Author

The design of the voltage-reference tube endurance test stations has been completed and parts accumulation has been started. Three test stations are planned, each accommodating two tubes. The systems are demountable and continually pumped with an ion pump on each chamber.

INTRODUCTION

The purpose of Contract NAS3-6469 is to continue the work started under Contract NAS3-2548 for the development of high-temperature ceramic rectifiers, thyratrons and voltage-reference tubes for long term use in nuclear electric space power systems. This phase of the development program is directed at establishing the validity of the technology and design concepts.

The performance objectives of the program are as follows:

(1) Thyratron having a continuous rating of 2000 volts, 15 amperes, 2000 volts PIV, 3200 cycles.

(2) Voltage-reference tube having a rating of 120 volts DC, 50 milliamperes, 3-percent accuracy over a current range of 25 to 75 milliamperes.

The tubes fabricated under this program will be given a series of electrical, mechanical and endurance tests. Tests will be conducted over a frequency range of 400 to 3200 cycles per second and at temperatures of 200 to 800°C in vacuum. Five tubes of each type will be given endurance tests at 800°C. The tests will be of at least 1000 hours duration.

TECHNICAL DISCUSSION AND PROGRESS

THYRATRON AND DIODE

The initial design of the high-temperature thyratron is shown in Figure 1. This design is similar to the design shown in Figure 28 of final report of Contract NAS3-2548. However, in the present structure the cathode assembly is mounted on a header with the heater inside the tube envelope. The cathode to be used in the initial tubes is a sintered, porous nickel cylinder with 32 slots, each 0.030-inch deep by 0.030-inch wide, running the full $1\frac{1}{4}$-inch length of the cylinder. The actual geometric area is approximately 25 square centimeters. A series of evaporation shields have been designed to surround the cathode so that there is no direct line-of-sight path to the outside shield. This type of structure should decrease the rate at which barium/barium oxide is lost from the cathode, since re-evaporation back to the cathode surface can take place. With the present cathode, the evaporation rate is of the order of 10^{-12} gram per centimeter squared per second at the operating temperature of $850^{\circ}C$.

In the present design, the evaporants from the cathode are directed to the shield. Re-evaporation from the cathode shield can take place and cause a flux of evaporant to the grid surface. After relatively long periods of time, the incident flux of barium/barium oxide to the grid surface would be expected to be controlled primarily by the shield temperature and surface condition. The barium/barium oxide arrival rate to the grid under these conditions does not lend itself to a meaningful analysis and can best be determined by extended operating tests. The fractional coverage of evaporant is a function of the re-evaporation rate from the adsorbing surface. Assuming the arrival rate to be constant, the work function reduction will be dependent on the evaporation rates from the grid and anode surface at the operating temperature. The results of investigations on test diodes (Contract NAS3-2548) indicated that pyrolytic impregnated porous graphite exhibits a minimum work function reduction under these dynamic conditions. Therefore, this material is incorporated as the grid and anode material in the present design.

The base graphite material is Grade 7479 Speer graphite which has a density of 1.51 grams per cubic centimeter. Graphite parts have been machined and sent to the General Electric Metallurgical Products Department

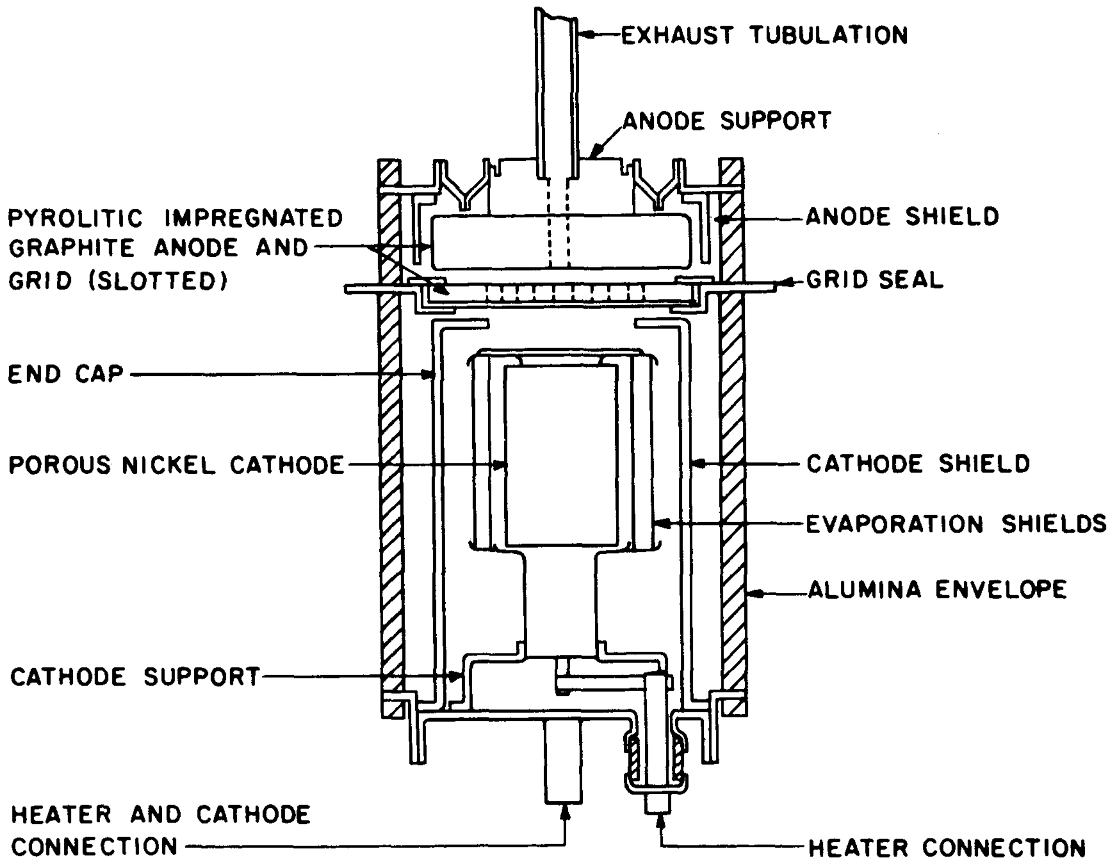

Figure 1 - Initial Design of High-Temperature Thyratron

for application of the pyrolytic coating. The coating thickness will be no greater than 0.005 inch, since thicker coatings can result in spalling.

The grid structure is mounted on the grid seal flange as shown in Figure 1. All of the seal flanges in the present design are Fernico and the butt-type seals will be effected by a palladium-cobalt brazing alloy to a high-temperature metalized ceramic coating.

A molybdenum anode supporting structure is joined by means of a tantalum spacer assembly to the molybdenum seal flange. The tantalum spacer assembly provides a long thermal path to the ceramic-to-metal seal and prevents direct radiation from the anode support to the seal. The graphite anode section is threaded onto the molybdenum support so that the anode-to-grid spacing is 1/8 to 3/16 inch. The tube envelope is 3 inches in diameter and is fabricated from a 97-percent alumina body.

It is planned to fabricate the initial tube without evaporation shields around the cathode. Operation in this manner will provide a bench mark for the grid and anode operating temperatures and provide data as to the minimum grid-control characteristics. With the evaporation shields removed, cathode evaporants will be adsorbed directly onto the cathode shield. Evaporants from the shield surface will eventually impinge on the grid surface. Operation of the tube with this open structure will allow a measure of the effectiveness of the grid material in inhibiting grid emission.

Parts accumulation is nearly complete with the exception of the pyrolytic grid and anode coatings. These are expected to be completed within two weeks.

Bell-jar tests have been started to determine the optimum grid and anode temperature with the present porous cathode structure. Mounted in the bell jar is a cathode of the type to be used in the tube. As shown in Figure 2, the cathode is surrounded by an anode shield which contains a 0.25-inch hole that permits electron flow to the moveable anode. The moveable anode structure is placed in front of the opening in the shield and the back emission is measured by applying a negative voltage to the anode. This experiment is presently in progress.

VOLTAGE REFERENCE - REGULATOR

The work effort on Contract NAS3-2548 was directed at investigating the volt-ampere characteristics of regulator tubes to temperatures of 800°C.

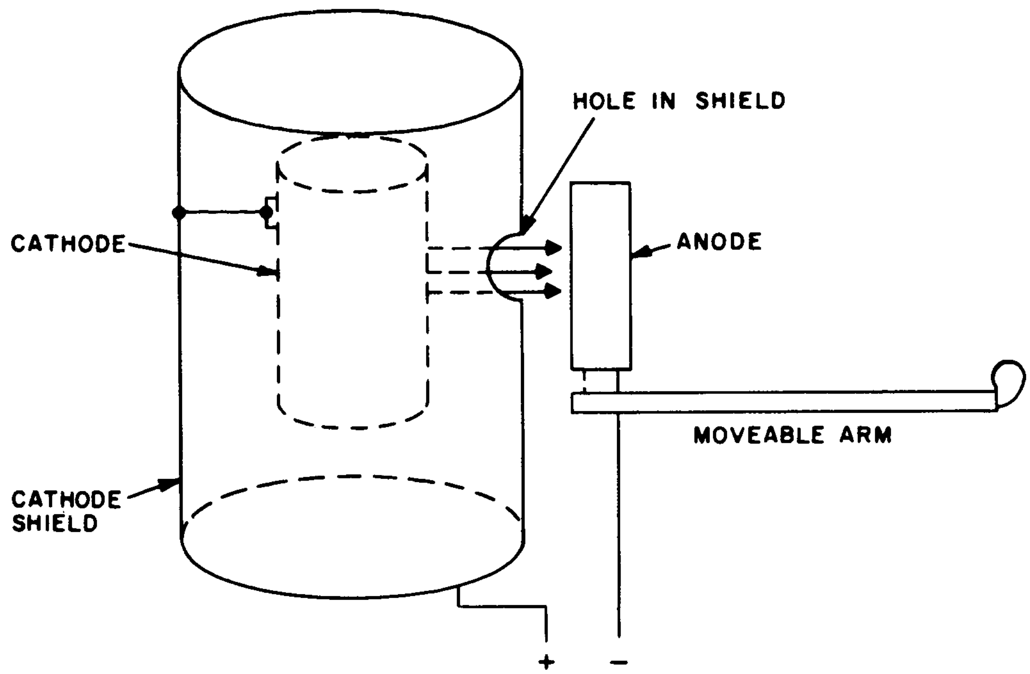

Figure 2 - Experimental Bell-Jar Diode

The regulation of a concentric anode design was found to be within 3 percent over the current range of 25 to 75 milliamperes at 800°C. A schematic of the tube structure is shown in Figure 3.

During the course of the initial work no extended operational tests were required. However, one tube was run for 500 hours at 800°C during which time a vacuum leak developed in the exhaust tubulation pinch-off. Although this initial work effort showed the feasibility of operating such devices at high temperatures, extended tests are needed to determine long-time operating characteristics and modes of failure. This is the task of this program.

Five tubes of the design shown in Figure 3 have been completed. An initial problem was encountered due to the expansion of the Fernico anode during the seal braze causing a short circuit across the 0.015-inch gap between the tubing and the molybdenum cathode cup. During the high-temperature seal braze, the anode came in contact with the molybdenum cup. At the brazing temperature, 1280°C to 1300°C, the nickel from the Fernico tubing alloyed sufficiently with the molybdenum to result in a short circuit. This was alleviated by increasing the cold spacing to 0.020 inch. Under operating conditions (800°C), the resulting starting gap will be approximately 0.017 inch.

Impurity gases, liberated from the structural members during life at high temperatures, can cause variations in the running voltage. For this reason, it is necessary to obtain a high degree of outgassing during processing and exhaust of the tube structures. Previous tubes were processed on oil diffusion pumped systems with cold traps. In order to insure a minimum of impurity gases during extended operational tests, the present tubes are being fabricated on an ion pump system capable of operating in the pressure range of 10^{-7} to 10^{-8} torr and at bake-out temperatures in excess of 900°C. An ion pump system has been modified to accommodate the gas loading system. A mechanical pump is used to rough out the system after which it is valved off. A trap in series with the roughing pump prevents oil vapors from backstreaming into the exhaust manifold. An external bell jar capable of attaining pressures on the order of 5×10^{-6} torr is used to maintain the external environmental pressure during bake-out.

The 1000-hour extended operating test will be run in the chamber shown schematically in Figure 4. Three systems are to be used, with each chamber containing two tubes. Each test station is continually pumped by means of an 8-liter-per-second triode ion pump. The tube temperature is

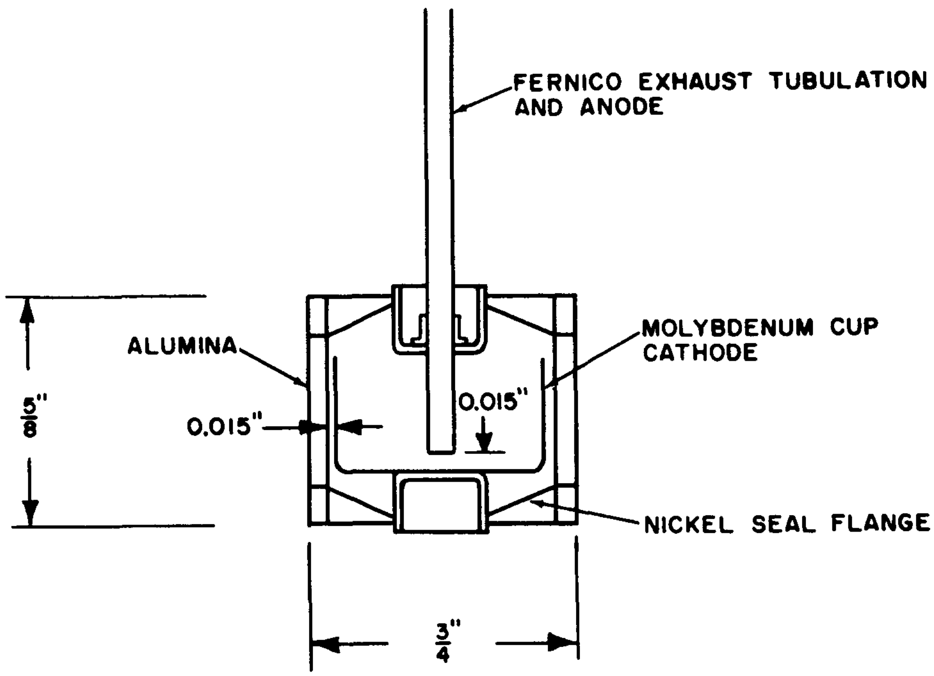

Figure 3 - Electrode Structure of Voltage-Reference Tube Containing a Concentric Anode

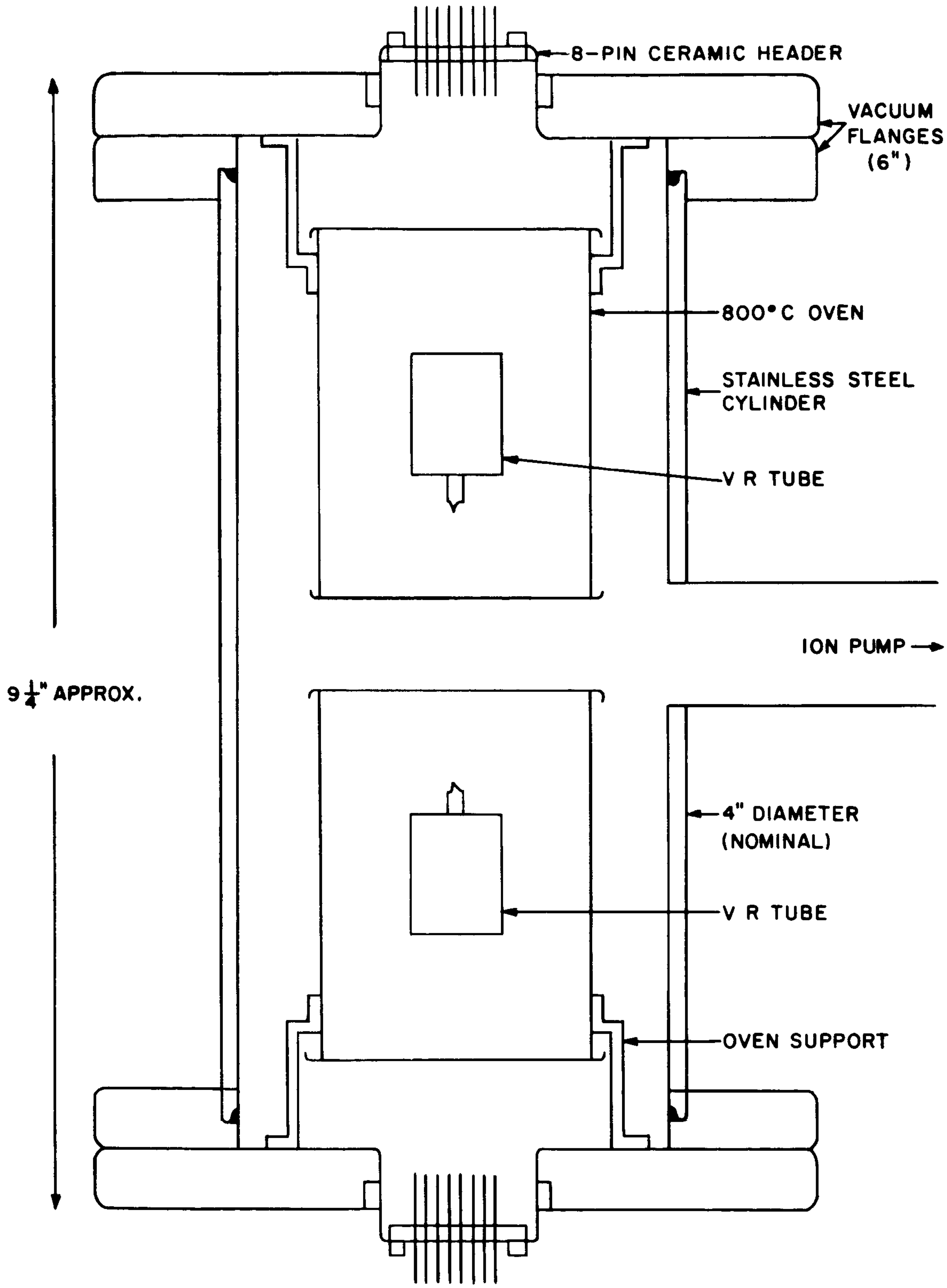

Figure 4 - Endurance Test Station for Voltage-Reference Tube

maintained by a 2 1/8-inch diameter, tungsten radiation heater. This heater is similar to the 4-inch diameter heater used on Contract NAS3-2548 for the high-temperature diode tests (Figure 5). The tube and heater connections are brought out through a ceramic pin feedthrough which is welded into the 6-inch diameter stainless-steel demountable vacuum flanges on both ends of the chamber. This type of system provides maximum versatility in the testing procedure. If a failure of one tube occurs, only one other tube has to be shut down. This minimizes delays in total time accumulation.

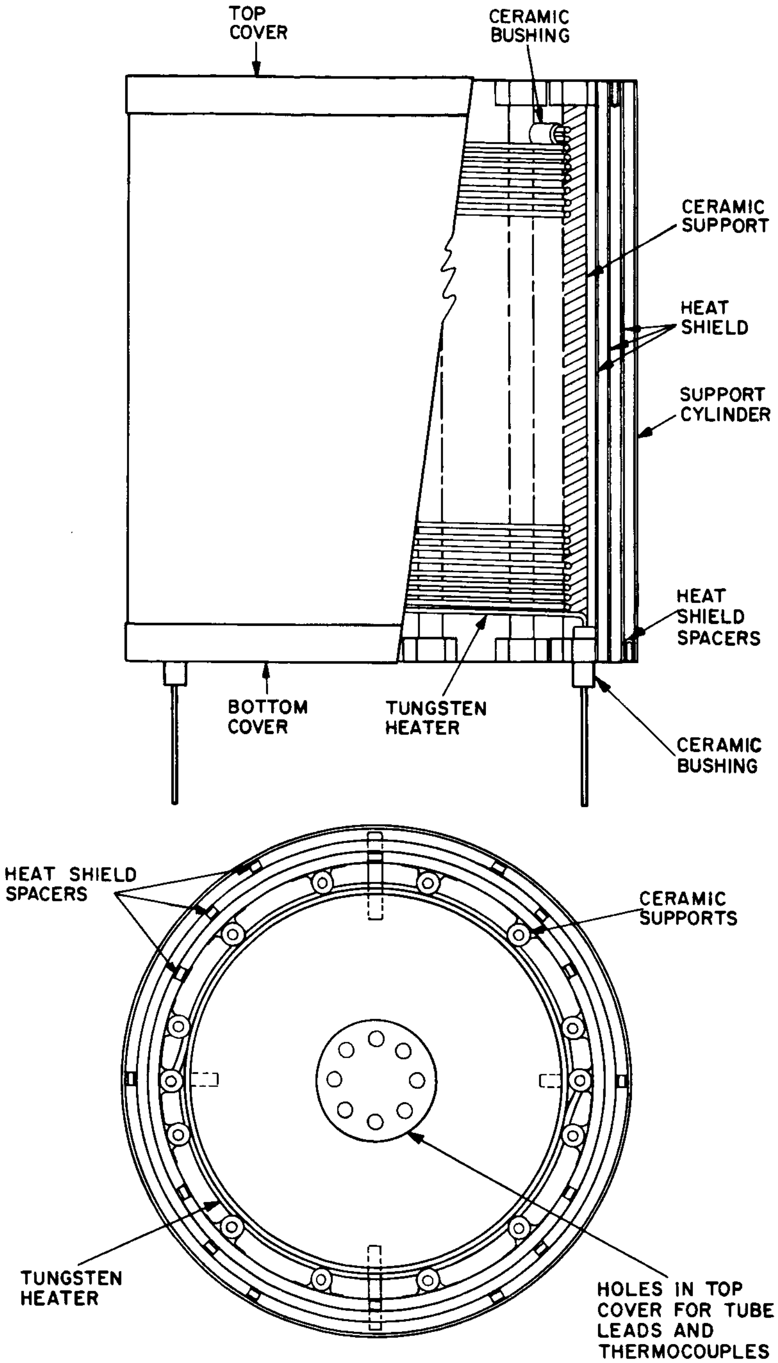

Figure 5 - Radiation Oven

PROGRAM FOR NEXT PERIOD

During the next period, the initial thyratron structure will be tested and tube fabrication for the endurance test will be started.

Testing of the initial (5) voltage-reference tubes will be completed and the endurance test will be started.

It is also expected that mechanical testing of both the thyratron and the voltage-reference tube structures will be started. It is planned to initiate tests on the envelope structures of both tubes and then proceed with the completed structures.

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ABSTRACT

This report describes the work effort during the first quarter of Contract NAS3-6469. The design of an initial high-temperature thyratron is described. A description of the voltage-reference tube and endurance test stations is given.