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Development of

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

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by

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Quarterly Progress Report No. 3

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SUMMARY

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The present phase of Contract NAS3-6469 is directed at advancing the high-temperature tube technology and establishing basic design data and concepts for gas tubes operating in high-temperature environments. During the first six months of the contract, basic designs were established for the high-temperature thyatron device and voltage-reference tubes, and data were obtained for tube temperatures up to 750°C. Based on these data, design changes were incorporated.

During this reporting period, six tubes were put on test. Of these, two tubes failed within a few hours because of vacuum leaks. One tube (No. 7), a hollow-anode structure, developed a vacuum leak in the grid seal, while another tube (No. 8) developed a crack in the molybdenum anode flange.

The remaining four tubes were tested at temperatures up to 760°C and over the frequency range of 60 to 3000 cycles per second. One tube was operated for approximately two hours at 6000 cycles per second at 1700 volts peak inverse voltage.

Endurance tests on the voltage-reference tubes have been started. The first tubes were operated for a total of 330 and 354 hours, respectively. Both tubes were operated at 50 milliamperes with a running voltage of 127 volts.

author

INTRODUCTION

The work effort in the second quarter of this program was directed at completing the fabrication of the initial design of high-temperature thyatron and reference tubes, while the effort during this reporting period was directed at completing the design tests on the initial tubes and incorporating required design and structural changes.

The two basic designs shown in Figures 1 and 2 have evolved. In addition, a hollow-anode tube structure was designed and two such structures were given limited testing with both tubes developing leaks in the metal support members. It is not planned to make further tests with this structure.

Of the nine thyratrons constructed on this contract, the first eight were fabricated with gold-copper seals and a low-purity ceramic body. Tube No. 9 and subsequent tubes are being fabricated with a high-purity Lucalox* alumina type body designated as A-976. The ceramic-to-metal seals are of the metallized type and are effected with palladium-cobalt brazing alloy. The need for the higher-purity alumina body was evidenced by the high leakage resistance between grid and anode when the lower purity alumina was used (Figure 3).

The test results on the nine tubes fabricated are as follows:

<u>Tube No.</u>	<u>Design</u>	<u>Test Results</u>
1	Figure 1 less cathode shields	Operated 3 hours - leak developed in exhaust tubulation
2	Figure 1 less cathode shields	Tube operated 80 hours - leak developed in grid seal
3	Figure 1 less cathode shields	Operated 2 hours - leak developed in cathode leader
4	Figure 1 less cathode shields	Operated 30 hours - leak developed in cathode leader
5	Hollow-anode structure	Leaked through cathode leader

*Registered Trade-mark of the General Electric Company

<u>Tube No.</u>	<u>Design</u>	<u>Test Results</u>
6	Figure 1	Operated 40 hours - leaked in grid seal
7	Hollow-anode structure	Leaked in grid seal
8	Figure 2	Molybdenum seal flange cracked
9	Figure 2	Presently on test - endurance run at 3200 cycles per second, 1700 volt PIV, 3 amperes ave., 720 ^o C wall temperature

TECHNICAL DISCUSSION AND PROGRESS

THYRATRON FABRICATION

The initial design of the high-temperature thyatron is shown in Figure 1 and the modified version in Figure 2. The first seven tubes fabricated were variations of the design shown in Figure 1, while the two remaining tubes were of the design shown in Figure 2. The design configuration shown in Figure 2 has a cathode area of approximately 70 square centimeters and is so designed that the cathode heater is external to the tube. The average emission densities are 0.6 and 0.2 ampere per square centimeter, respectively.

As shown in both Figures 1 and 2, the cathode structure consists of two concentric, slotted cylinders. The slots are so aligned that there is no direct line-of-sight evaporation from the cathode to the cathode grid volume. The gas discharge path is radially outward from the cathode and then up through the grid slots to the anode. Because of the tight cathode and grid baffling, both tubes exhibit a positive grid control characteristic.

As discussed in Quarterly Progress Report No. 2 (NASA CR-54478), the initial tubes were fabricated using a 94-percent alumina body ceramic. Subsequently, a 99-percent alumina body ceramic was substituted to reduce the anode-to-grid leakage resistance at high ambient temperatures. The use of the 99-percent alumina body allows a higher temperature ceramic-to-metal seal than could be used with the 94-percent body. A palladium-cobalt alloy, which is brazed at approximately 1300°C , is presently being used. The metallized ceramic coating required to effect the braze is sintered at a temperature in excess of 1800°C . Previous attempts at using the palladium-cobalt braze failed because the braze material alloyed with the low-temperature metallized coating. (This seal technique has yet to be proven by endurance tests.) Both molybdenum and Kovar have been used for the anode seal flange, however, our experience with molybdenum indicates the high brazing temperature causes the flange to become embrittled.

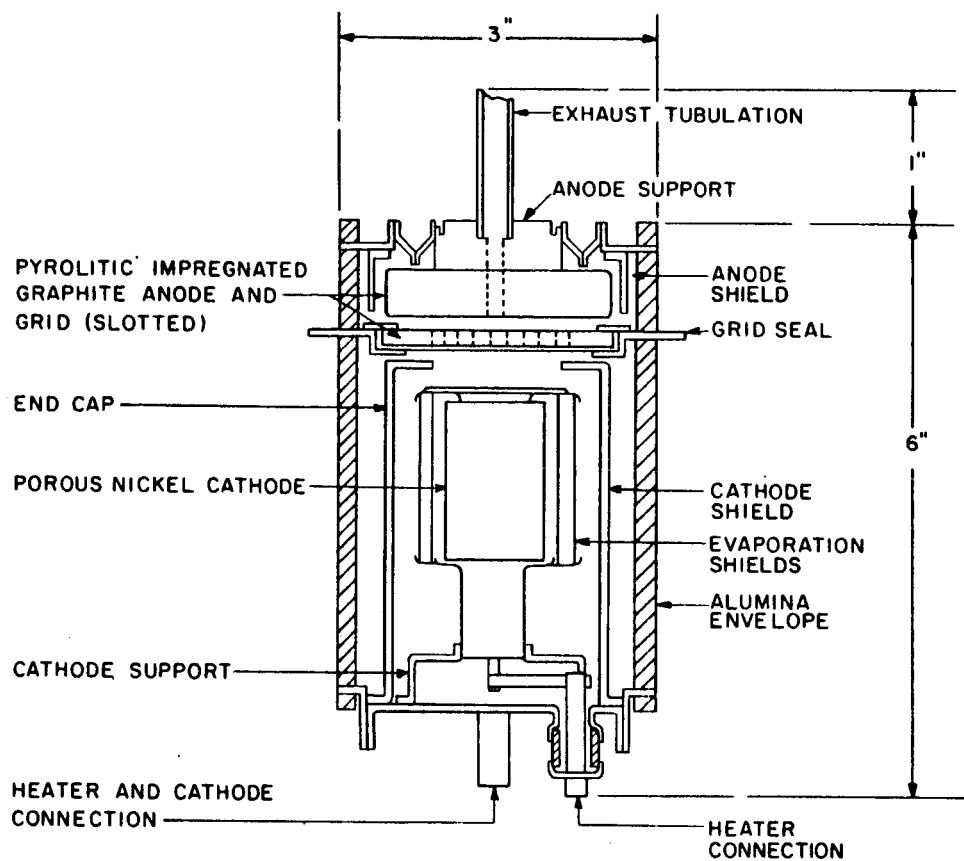


Figure 1 - Initial Thyratron Design

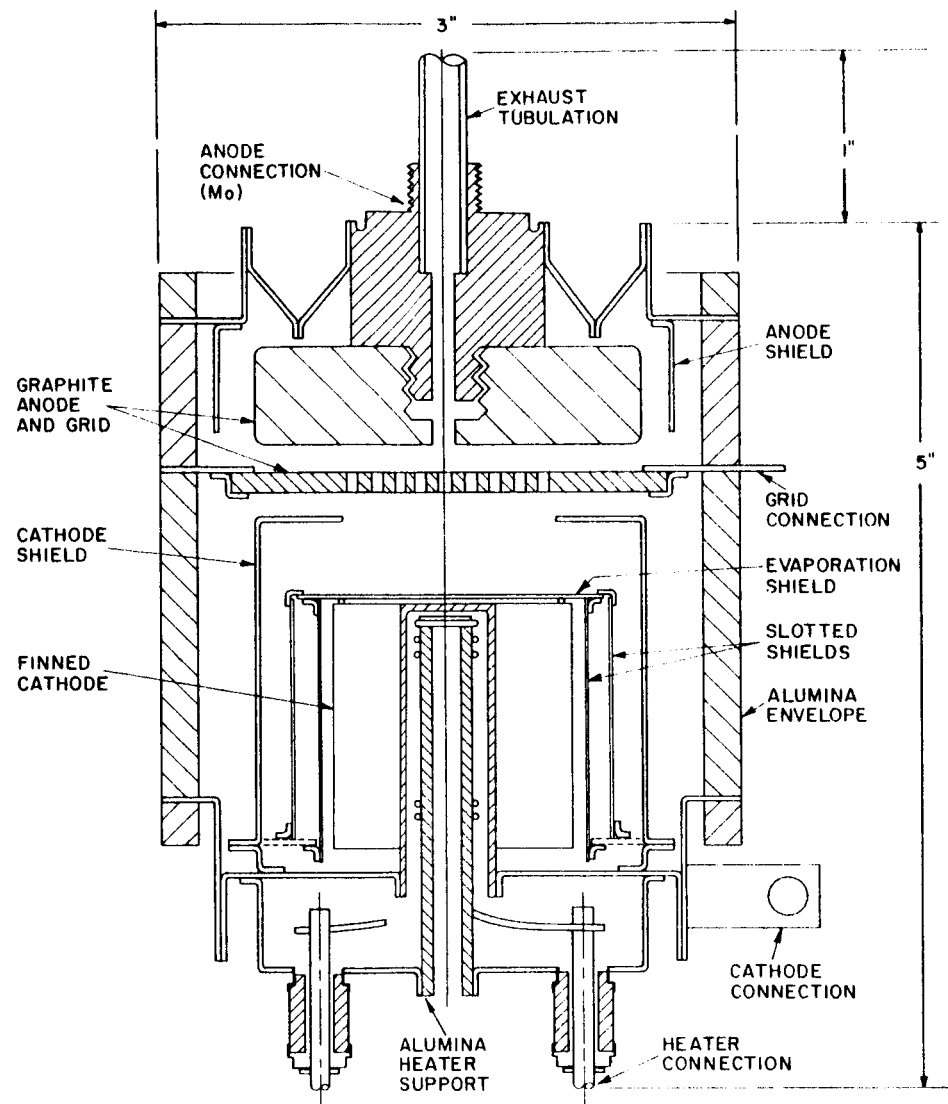


Figure 2 - Finned Cathode Tube Structure

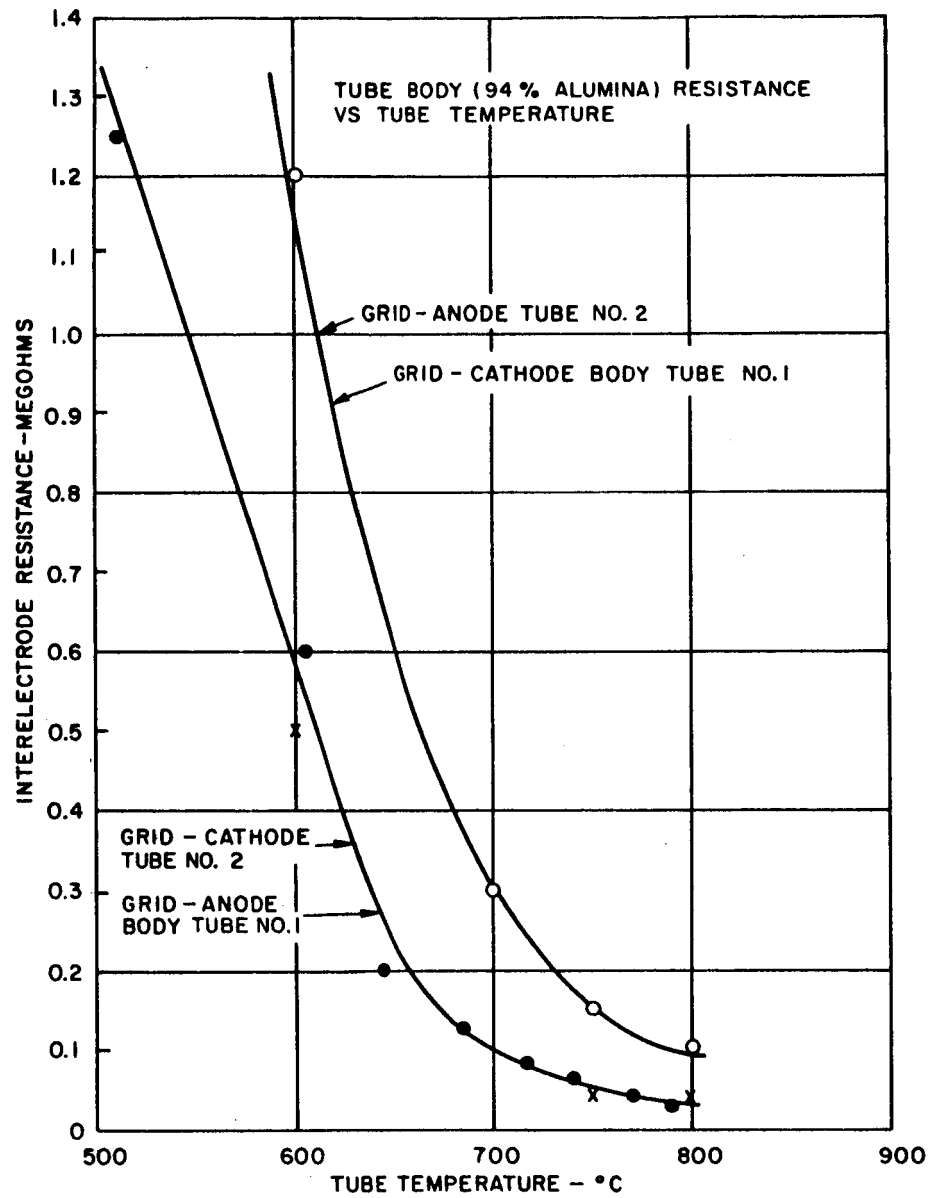


Figure 3 - Graph Showing Resistance of the Ceramic Tube Body

THYRATRON TESTS

Figures 4 and 5 show typical grid characteristics taken on tubes 4 and 6. (Both of these tubes have the same anode and grid assembly, but tube 4 was fabricated without evaporation shields surrounding the cathode.) The dashed curve represents the DC grid characteristic. Typical grid control voltages for peak voltages of 200 to 1700 volts were from 10 to 18 volts at a wall temperature of 750°C over the frequency range of 60 to 3200 cycles per second. In all tubes tested it has been observed that the grid firing voltage decreases as the tube heats up due to the discharge. This condition may be caused by the onset of grid emission or by leakage across the anode-grid seal.

After 30 hours of operation tube 4 was run for approximately two hours at a frequency of 6000 cycles per second. There was no loss of grid control during this test, indicating the deionization or recovery time of the tube is less than 80 microseconds.

Tube 8 which has the structure shown in Figure 2, was the first finned cathode tube tested. The initial tests showed the tube to be hard starting and the grid firing voltage to be 120 volts or higher, because of the tight baffling around the cathode. Subsequently, tube 9, which has the structure shown in Figure 6, was fabricated with the slot width in the evaporation shields increased by 60 percent. During the initial operation a 200-volt grid pulse was required to start the tube. After aging for a period of about 3 to 4 hours, the critical grid firing voltage dropped to 35 volts. This tube has been started on endurance test at 3200 cycles. The test conditions are the following:

Tube wall temperature - 730°C
Anode temperature - 650°C
Peak inverse voltage - 1700 volts
Tube current (average) - 3.5 amperes
Tube voltage drop - 14 volts

The initial rate of rise of the peak inverse voltage has been measured at 90 volts per microsecond with the initial peak to 1400 volts.

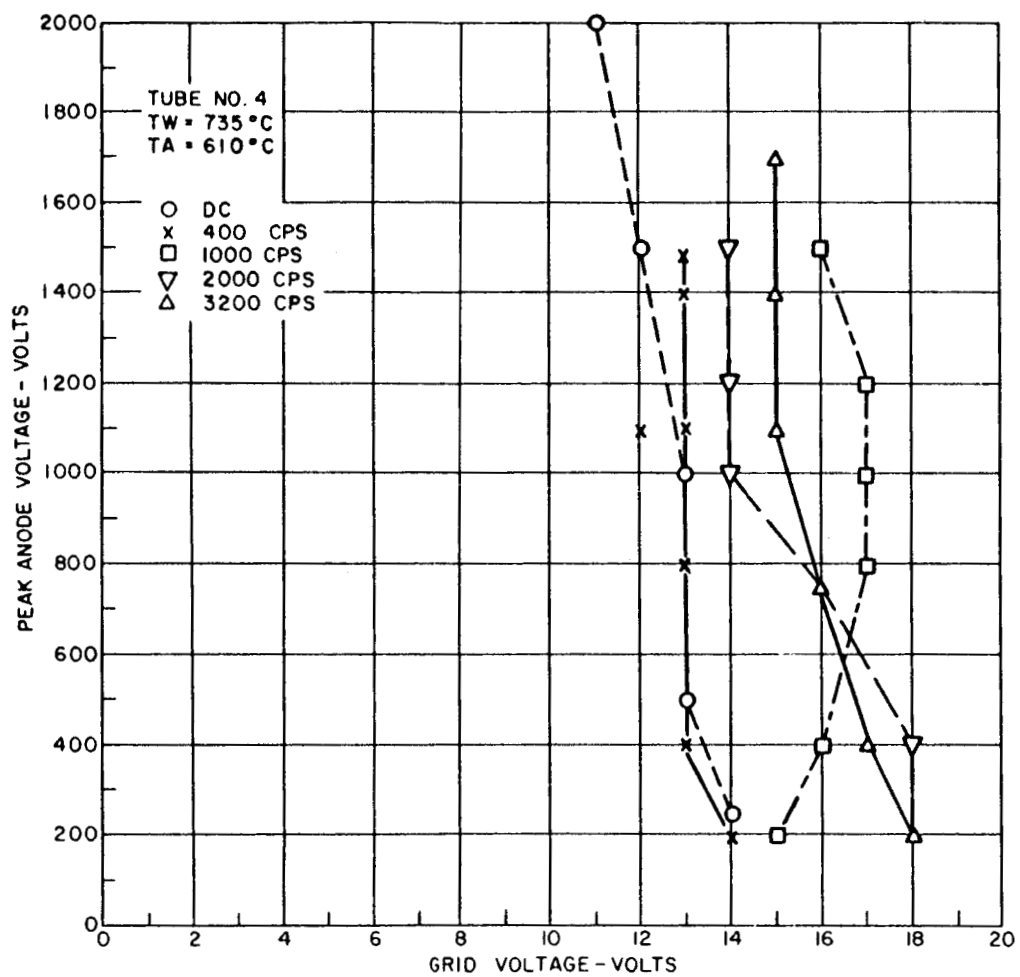


Figure 4 - Grid Characteristics of Tube No. 4

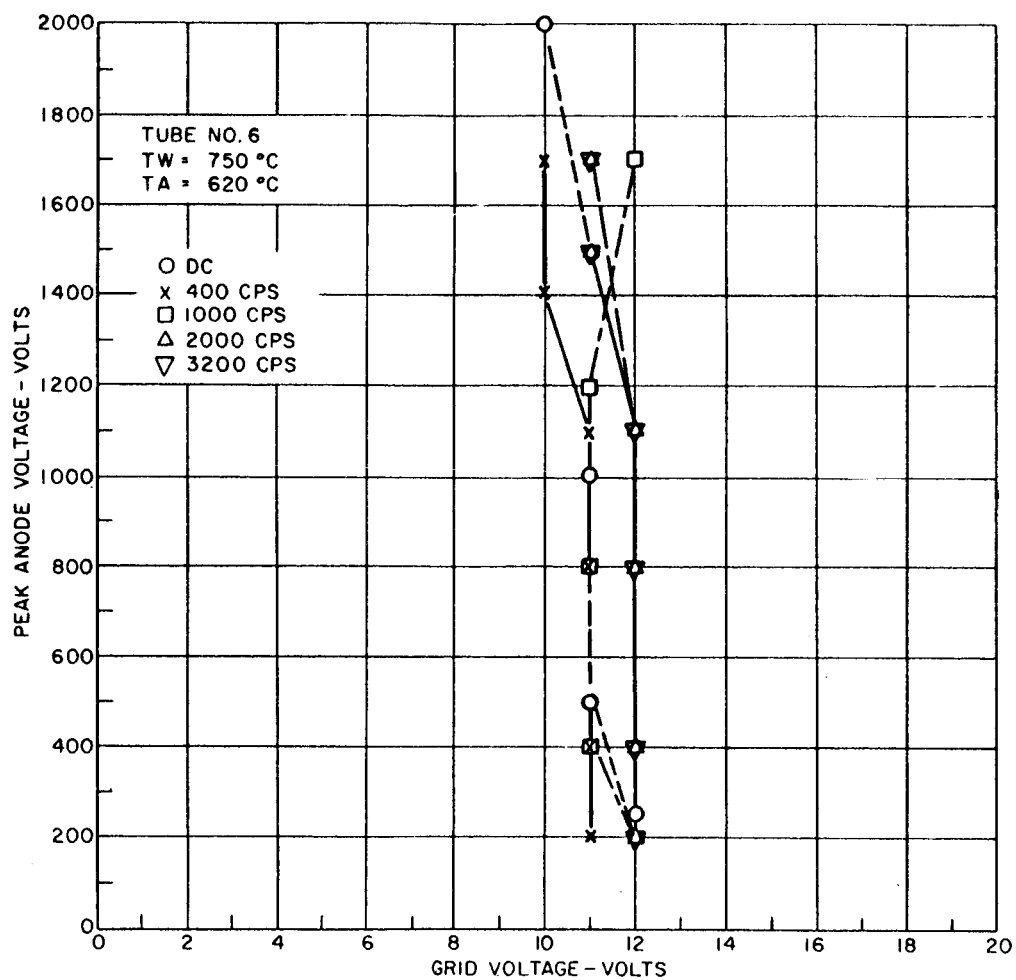


Figure 5 - Grid Characteristics of Tube No. 6

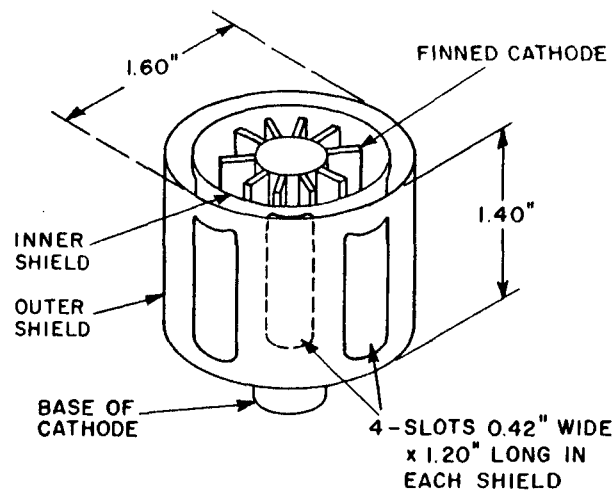


Figure 6 - Cathode Shield

VOLTAGE-REFERENCE TUBES

Endurance tests on the voltage-reference tubes have been started. The first set of tubes were processed at 900°C for one hour and loaded with neon to 20 torr at room temperature. A total of 330 and 354 hours, respectively, was accumulated on both tubes. The test conditions were at 50 milliamperes with the initial running voltages of 127 and 120 volts, respectively. Both tubes were operated for 100 hours at 400°C and then at 800°C for the remainder of the test. Failure of both tubes resulted from a gradual increase in running voltage. This suggests a gas clean-up condition caused by sputtered cathode material or the release of contaminants causing a rise in the running voltage. The rate of gas clean-up is proportional to the current whereas the rate of evolution of contaminants would be expected to increase exponentially with temperature. In either case a reduction in tube current may be necessary to extend the operating time. Evaluations are presently being made on the operating characteristics of tubes loaded to a higher pressure than was used on the initial endurance test devices.

PROGRAM FOR NEXT PERIOD

During the next period, endurance tests will be continued on the high-temperature thyratron structure. Due to the inability to run endurance tests under full load conditions, separate tests will be run under high-voltage low-current conditions and high-current (15 amperes) low-voltage conditions.

Endurance test on the voltage-reference tubes will also be continued and experiments will be run to determine optimum gas fill pressure and electrode temperatures under operating conditions.

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ABSTRACT

This report describes the work effort during the third quarter of Contract NAS3-6469. The high-temperature thyatron tube designs are discussed as well as some performance tests. A 1000-hour endurance test has been started on one tube operating at a wall temperature of approximately 750°C. Operational tests on the voltage-reference tubes are also presented.