THE UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

QUARTERLY PROGRESS REPORT NO. 17

FOR

RESEARCH AND DEVELOPMENT ON HIGH-POWER CRESTATRONS

FOR THE 100-300 MC FREQUENCY RANGE

This report covers the period July 1, 1964 to October 1, 1964

Electron Physics Laboratory
Department of Electrical Engineering

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J. E. Rowe, Director
Electron Physics Laboratory

Project 03783

NAVY DEPARTMENT BUREAU OF SHIPS
ELECTRONICS DIVISION
CONTRACT NO. NObsr-81403
PROJECT SERIAL NO. SF0100 201
TASK NO. 9294

October, 1964

ABSTRACT

The data obtained in a beam analyzer on a P_{μ} = 20 hollow-beam electron gun is presented. Certain defects in the gun as well as the beam analyzer require that these data be redone.

The final model of the 100-watt Crestatrons to be constructed on this program is described. Performance data and the required environmental tests were obtained and are summarized in this report. On the basis of these results construction of the three final tubes appears to be warranted.

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LIST OF ILLUSTRATIONS

PERSONNEL

Scientific and Engineering Personnel		Time Worked in Man Months*
G. Konrad	Associate Research Engineer	.27
C. Rhee	Research Assistant	1.53
Service Personnel		.16

* Time Worked is based on 172 hours per month.

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1. Introduction (G. T. Konrad)

Contract Nobsr-81403 comprises a research and development program on high-power 100-300 mc Crestatrons. The aim is to construct compact 100-watt Crestatrons employing permanent magnet focusing. Initially the tubes are be tested in a solenoid until they meet electrical specifications, but ultimately the permanent magnet focused tubes employing a depressed potential collector will be ruggedized so as to meet environmental specifications. This work is being conducted by the Bendix Research Laboratories on a subcontract from The University of Michigan.

Theoretical as well as experimental studies on high-perveance hollow-beam electron guns, in addition to electrostatic focusing systems initiated some time ago on this program, are being continued by The University of Michigan. The ultimate goal of these studies is to demonstrate the feasibility of using electrostatically focused, high-power, hollow electron beams in microwave devices. In addition an electron gun design compatible with a high-power vhf Crestatron is to be worked out.

2. Work on Electrostatically Focused Guns (C. K. Rhee)

The $P_\mu = 20$ gun with a mean beam diameter of 1.076 inch was tested in the beam analyzer during the past quarter.

As the heater characteristics shown in Fig. 2.1 indicate, a much higher filament temperature than expected was required in order to obtain the designed beam current. This clearly indicates that the cathode emission is low. Figure 2.2 shows the percent beam transmission vs. beam voltage. The multi-grid sampling collector used in the beam analyzer was not biased throughout this focusing test because of too high average collector currents. The beam transmission is poor but it is expected that the collector biasing would increase the beam transmission appreciably. There is a rather large number of secondary electrons returning to the gun anodes.

The various beam profiles were taken for different lens voltages and for several distances between the gun and the collector. The gun was tested at a beam voltage of 1000 volts without collector biasing. A mechanical defect in the beam analyzer permitted only the left half of the beam to be plotted. Representative plots are shown in Figs. 2.3 through 2.5. Figures 2.3 and 2.4 show the beam shape as a function of lens voltage for two different anode-collector distances. In Fig. 2.3 it is noticed that the beam thickness is well controlled by the lens. A lens voltage of -950 volts gave the best beam transmission. As the distance between the gun and collector rods is increased, the beam becomes thicker due to space-charge forces. It is also noticed that the center of the beam is shifted. Figure 2.5 shows a plot of the beam shape as a function of the anode-collector distance for a lens voltage of -950 volts for which the maximum collector current was obtained.

In view of the above results it will be necessary to retest the gun during the coming quarter. For this purpose a new cathode has been installed and the necessary repairs in the beam analyzer have been made.

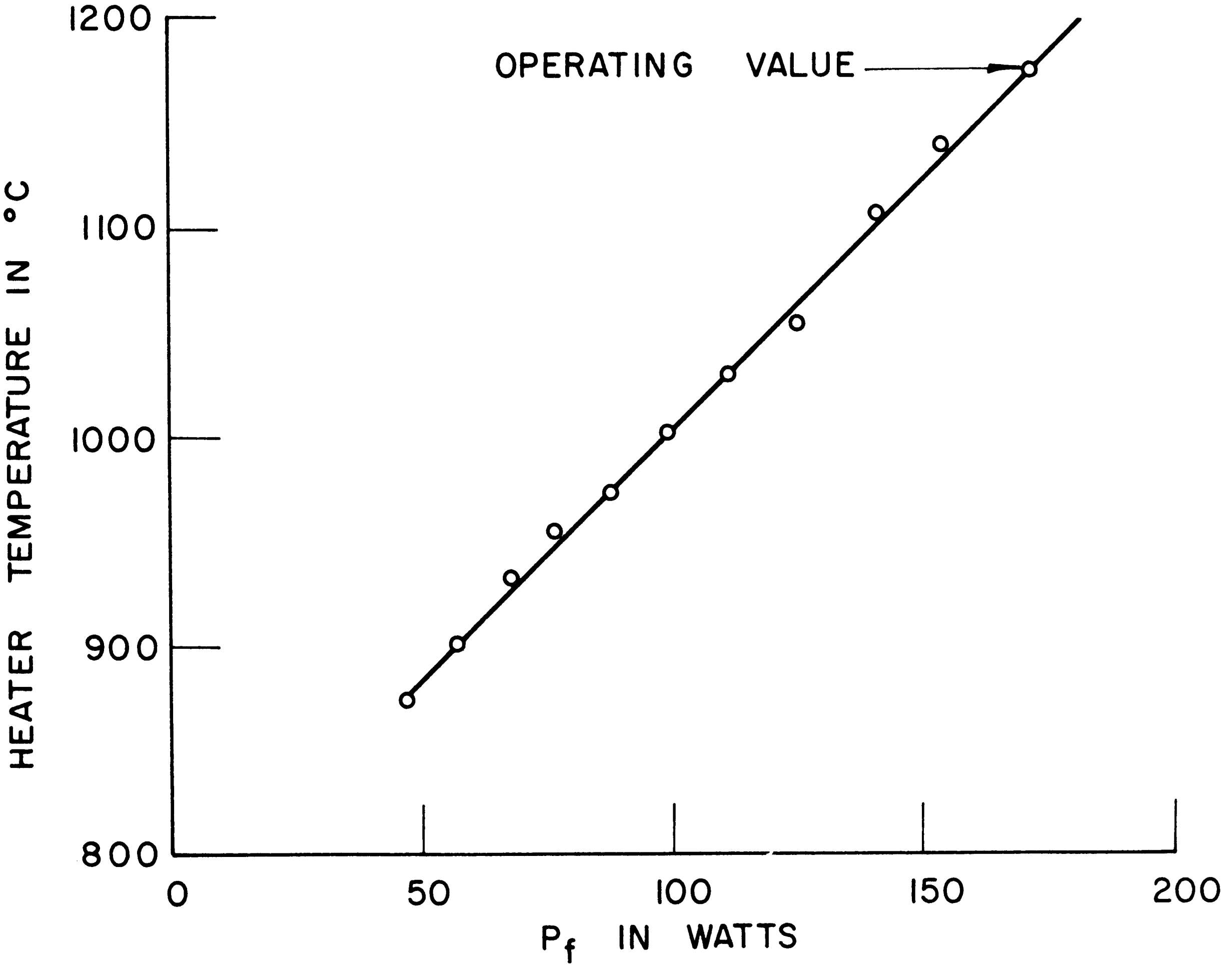

FIG. 2.1 FILAMENT TEMPERATURE VS. FILAMENT POWER.

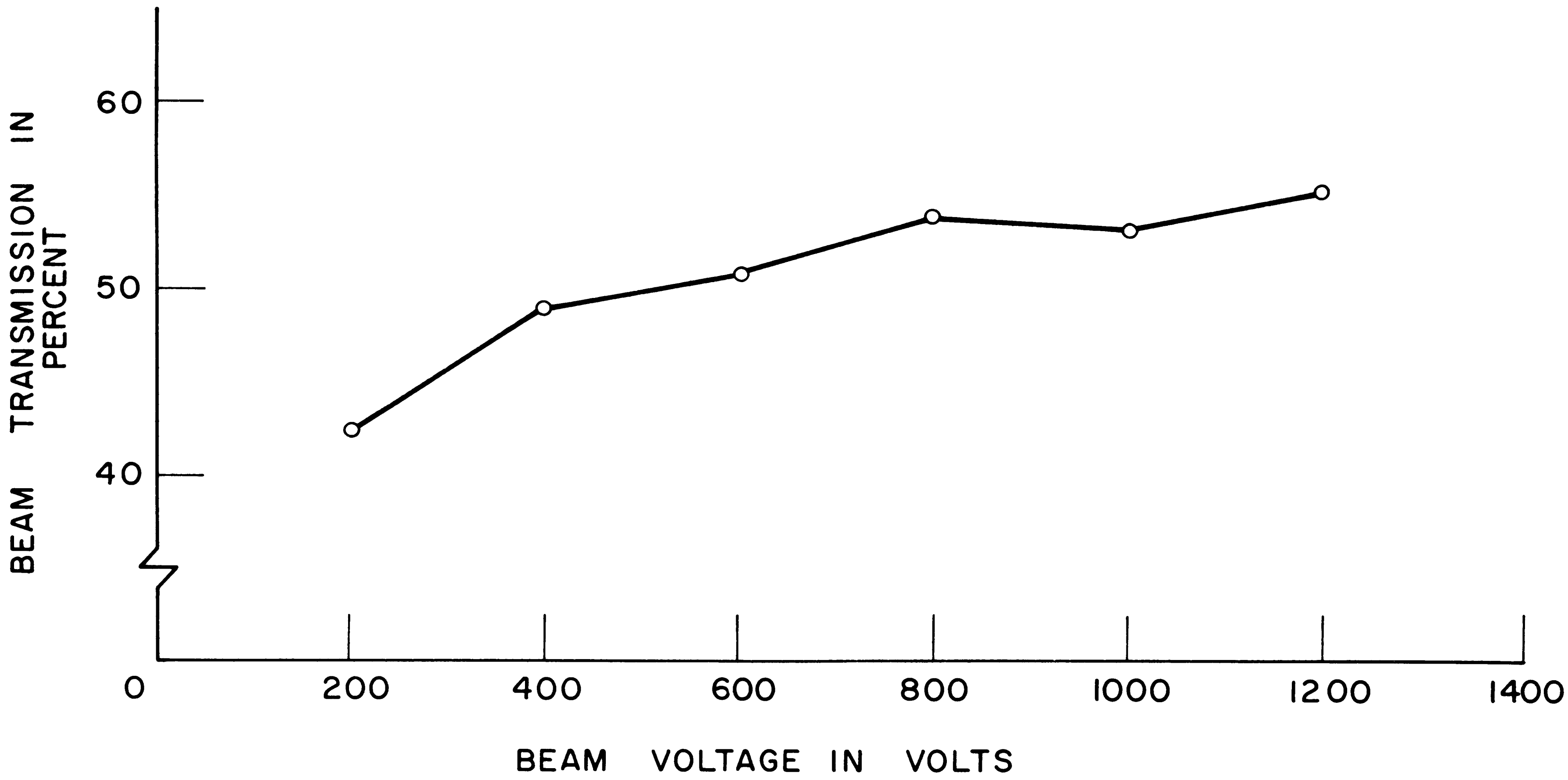

FIG. 2.2 PERCENT BEAM TRANSMISSION VS. BEAM VOLTAGE.

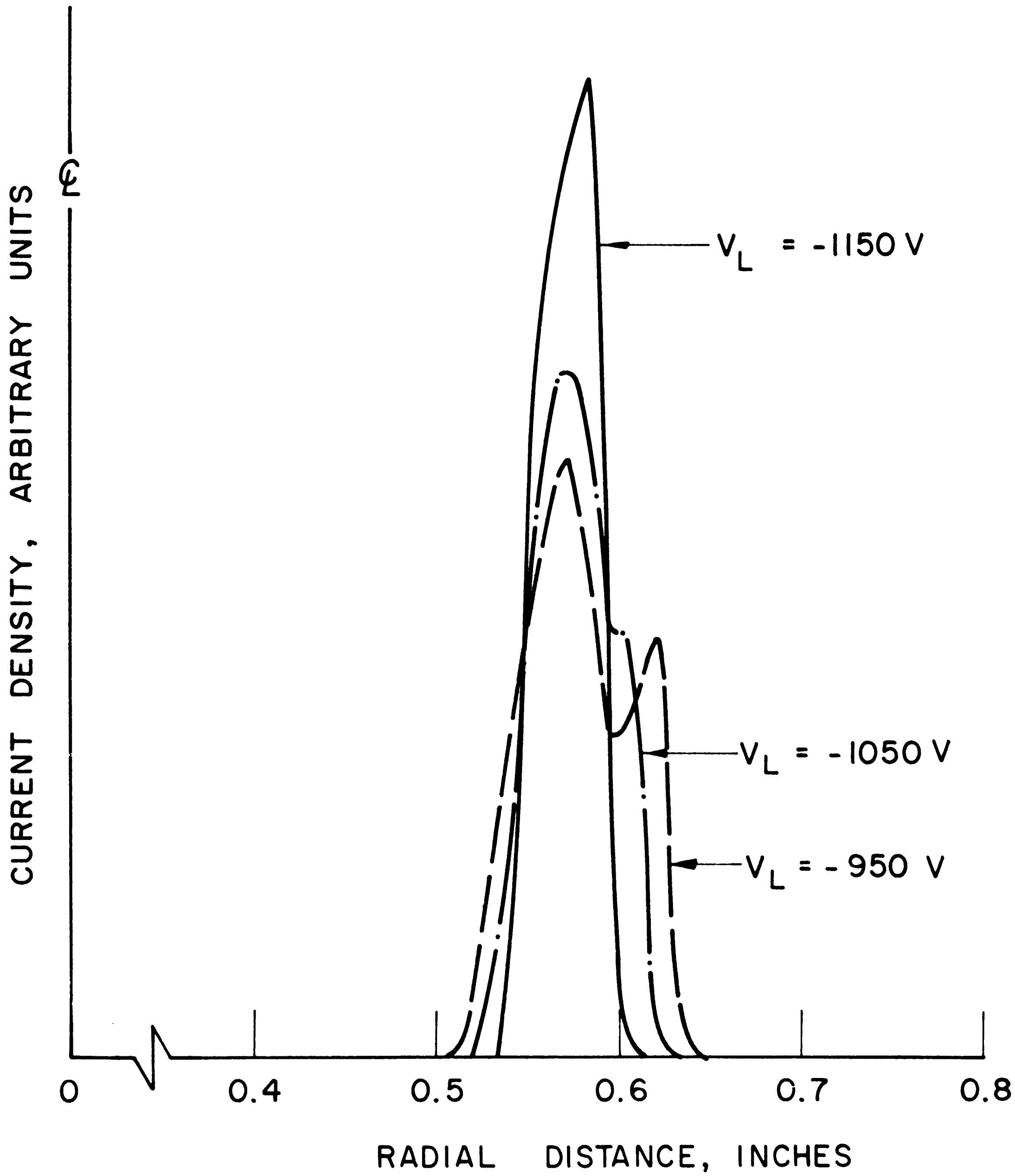

FIG. 2.3 COMPARISON OF BEAM PROFILES AS A FUNCTION OF LENS VOLTAGE AT A DISTANCE OF 0.10 INCH FROM THE FINAL GUN ANODE.

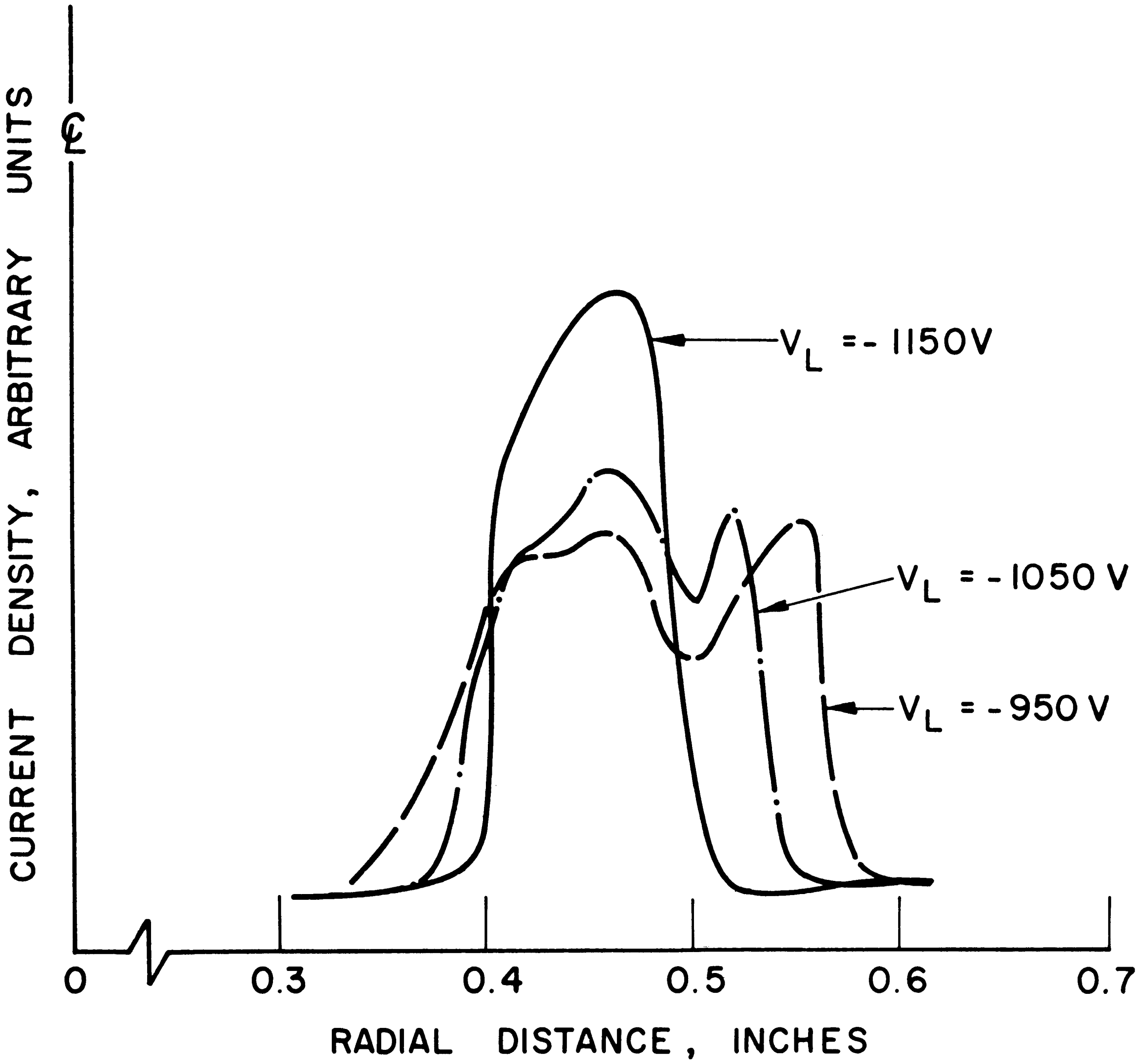

FIG. 2.4 COMPARISON OF BEAM PROFILES AS A FUNCTION OF LENS VOLTAGE AT A DISTANCE OF 0.50 INCH FROM THE FINAL GUN ANODE.

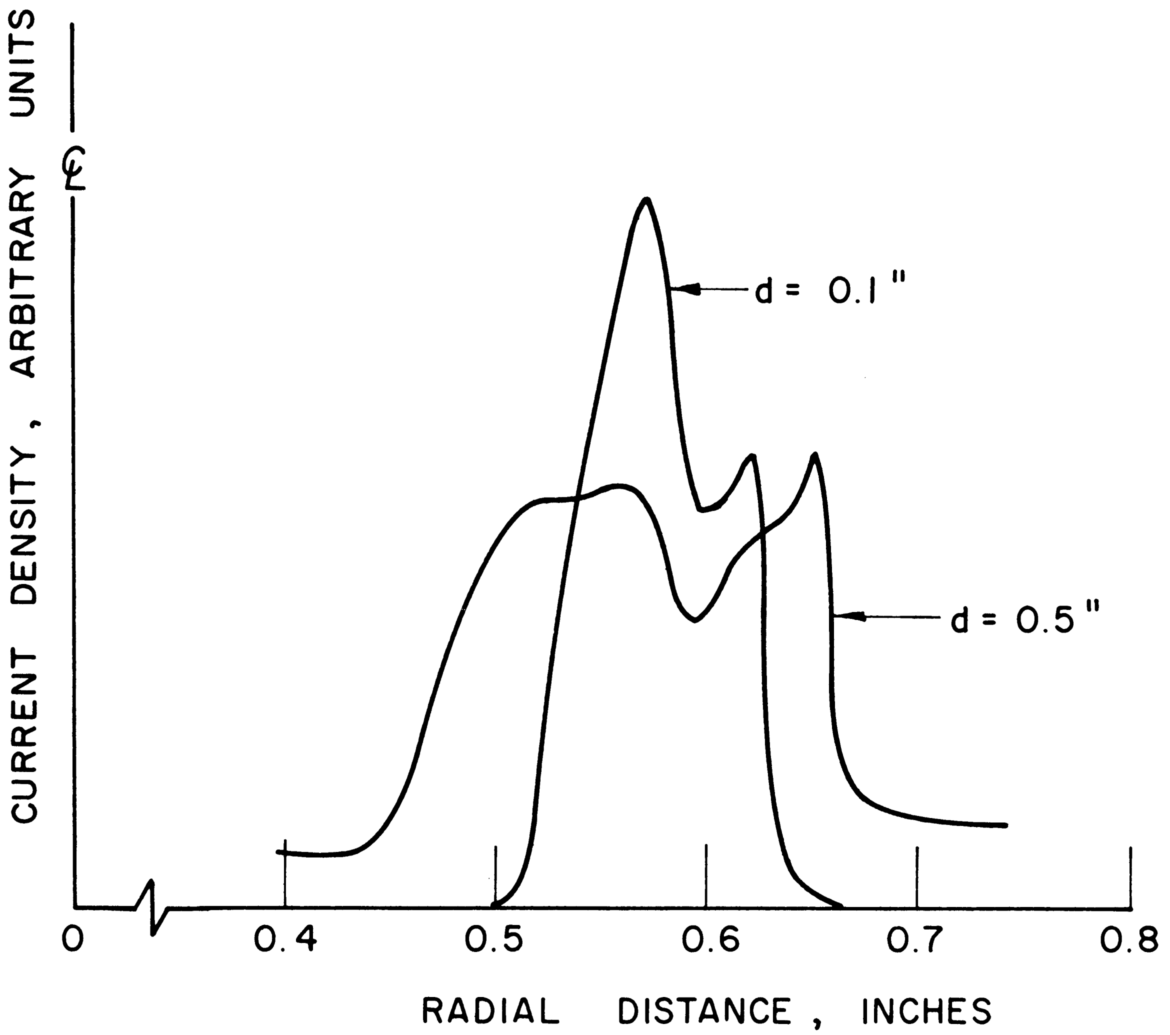

FIG. 2.5 COMPARISON OF BEAM PROFILES AS A FUNCTION OF ANODE-COLLECTOR SPACING FOR LENS VOLTAGE = -950 V.

3. Work Conducted at the Bendix Research Laboratories*

3.1 Introduction. The work on the development program to build a 100-watt, 100-300 mc traveling-wave amplifier has been divided into two tasks, the first of which is completed.

TASK I

This task resulted in the design and fabrication of a tube (TW-147) compatible with solenoid operation which met or exceeded the specified minimum power output across the required frequency band. However, the tube exhibited inverse saturation characteristics and the minimum power output point occurred at the low end (100 mc) of the band.

This task also included the design of a permanent magnet focusing structure, but this effort was deferred so that an evaluation of several focusing schemes applicable to this tube could be included. Consequently, the selection and fabrication of a particular focusing structure is to be performed during Task II.

TASK II

Three tubes which meet the electrical and environmental contractual requirements will be fabricated and delivered. These tubes will incorporate both electrical design modifications, to more reliably meet the power output requirements at the low frequency end of the band, and a completely new mechanical design. Important mechanical design considerations included ease of parts fabrication and assembly, reduction in size and weight, and changes required to meet the environmental specifications.

These tubes will utilize the focusing method as determined best by mutual agreement, after reviewing the computations for several focusing

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* This material was submitted by A. G. Peifer of the Bendix Research Laboratories.

3.2 Tube TW-148-1. The first tube assembled developed a shorted helix; consequently, only the electron gun tests were performed. The gun operated at design perveance and at full rated beam current. However, Anode No. 1 intercepted excessive beam current at rated parameter values, but was held within an acceptable limit by increasing the solenoid magnetic field. Upon disassembly, an inspection of the gun revealed that the outer electrode stack was not properly aligned. Thus, a skewed electric field was produced in the critical anode-to-cathode space. This electron gun was used in the first two assemblies of Tube TW-148-2.

3.3 Tube TW-148-2. This tube was assembled with 2 to 8 db of loss added to the helix circuit. The gun from Tube No. 1 was used in this tube. The small-signal band center occurred at about 250 mc. The electronic gain was 8 db at 100 mc, 13 db at 200 mc, 13 db at 300 mc and 12 db at 400 mc. The net gain ranged from 4.5 to 7 db across the band. A constant 70-watt input level was used in determining this gain. Figure 3.1 shows the power out and gain vs. frequency for 7-watt input signal.

Tube No. 2 was then rebuilt and designated 2R. The same electron gun was used, but the 2 to 8 db of helix loss was removed. The gain increased 1 to 2 db over the same circuit with added loss. Net gains ranged from 6 to 9 db with saturated outputs exceeding 100 watts. Figure 3.2 shows the power output vs. frequency for both a 7-watt and a 30-watt drive input signal. Tube No. 2 was rebuilt a second time with a new gun which had the electrodes in the proper position. This gun operated as predicted, but little difference was noted in either gain or power output, as compared to Tube 2R. After extensive testing, this tube developed a leak and became inoperable.

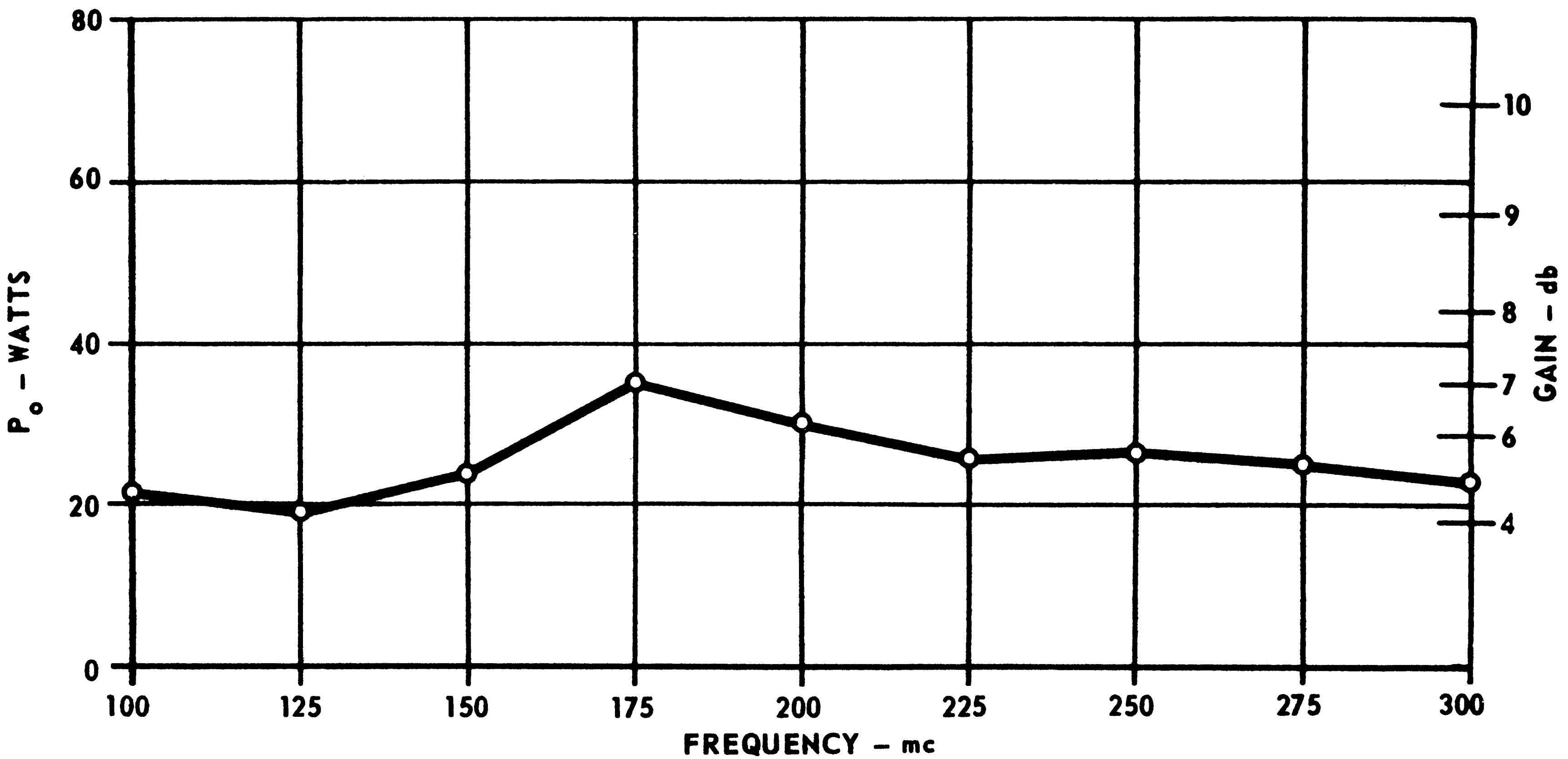

FIG. 3.1 POWER OUTPUT VS. FREQUENCY WITH 7-WATTS INPUT DRIVE; TW-148-2.

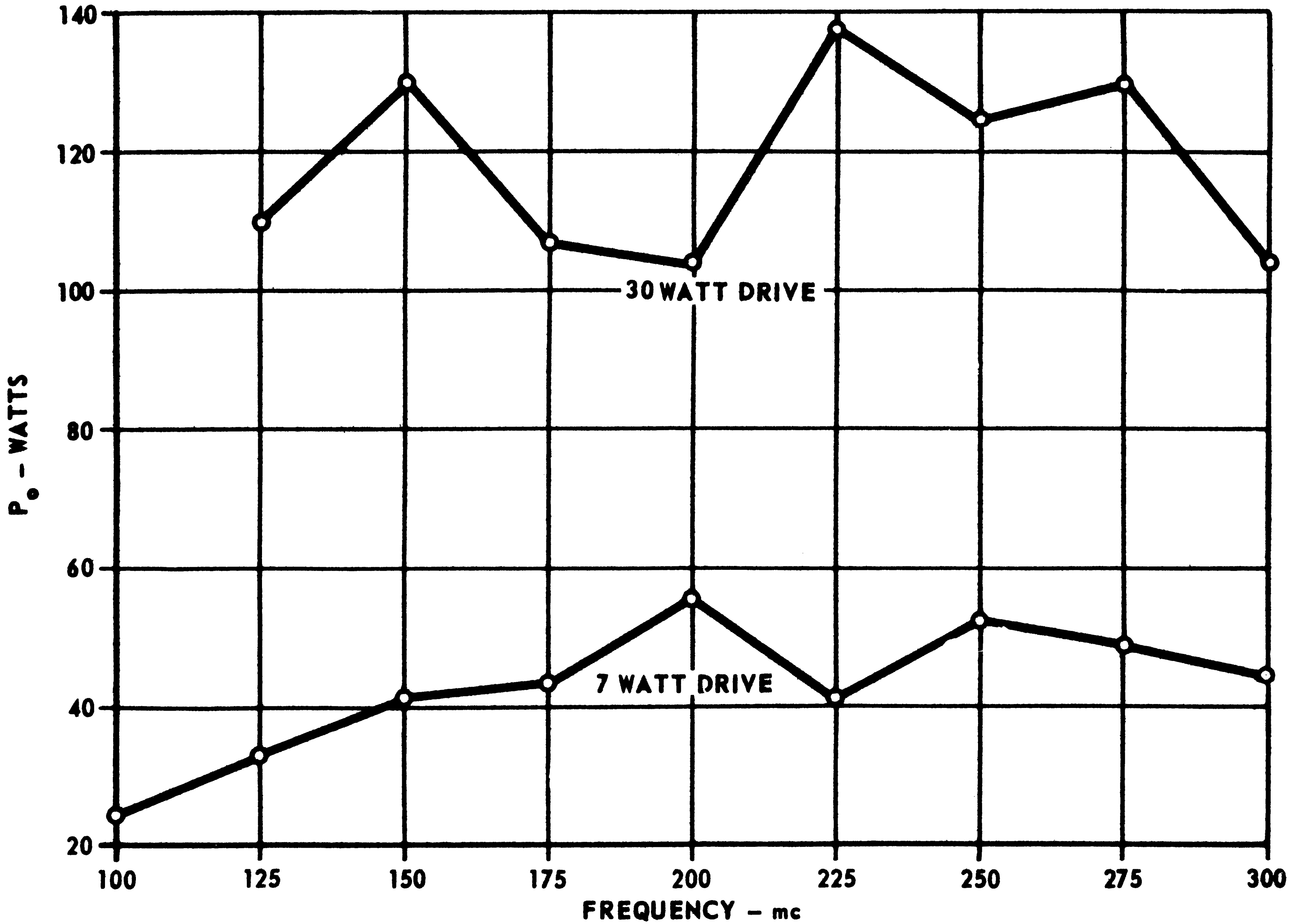

FIG. 3.2 POWER OUTPUT VS. FREQUENCY FOR TW-148-2R; 7-WATT AND 30-WATT DRIVES.

Gun No. 1 was put back into the tube and the tube designated 2RRR. This tube is now being used as a driver in the testing of subsequent tubes.

3.4 Tube TW-148-3. As a result of the extensive tests performed on TW-148-2 the r-f structure was lengthened to provide more gain. In addition, the output r-f match was redesigned for a lower cutoff frequency to improve the tube performance at and near 100 mc.

Tube TW-148-3 was assembled and processed. Partial gun failure required immediate replacement of the gun. The tube was then designated 3R. This longer circuit had no added loss and utilized the new output r-f matching section. The gain of Tube 3R, both small and large signal, was within acceptable limits. Figure 3.3 shows a plot of power output vs. power input at several frequencies.

After the data shown in Fig. 3.3 was taken, the tube was subjected to the nonoperating vibration tests. The tube was vibrated parallel to the axis of the tube with a frequency of 5 c.p.s. to 500 c.p.s. and at an amplitude of 0.12 inch or 5 g, whichever was the limiting value The rate of frequency change was such that 5 c.p.s. to 500 c.p.s. and back to 5 c.p.s. took about 15 minutes. The test continued for 60 minutes.

Tube 3R was then thoroughly retested. Figure 3.4 shows the power output vs. power input data obtained. As can be seen, no significant changes occurred as a result of the vibration tests.

The tube was then subjected to shock tests and again no adverse effects were detected. The test consisted of a 15 g shock for 11 ± 1 millisecond duration with six shocks in each of three mutually perpendicular directions. Figure 3.5 shows the power output vs. power input characteristics of the tube after shock.

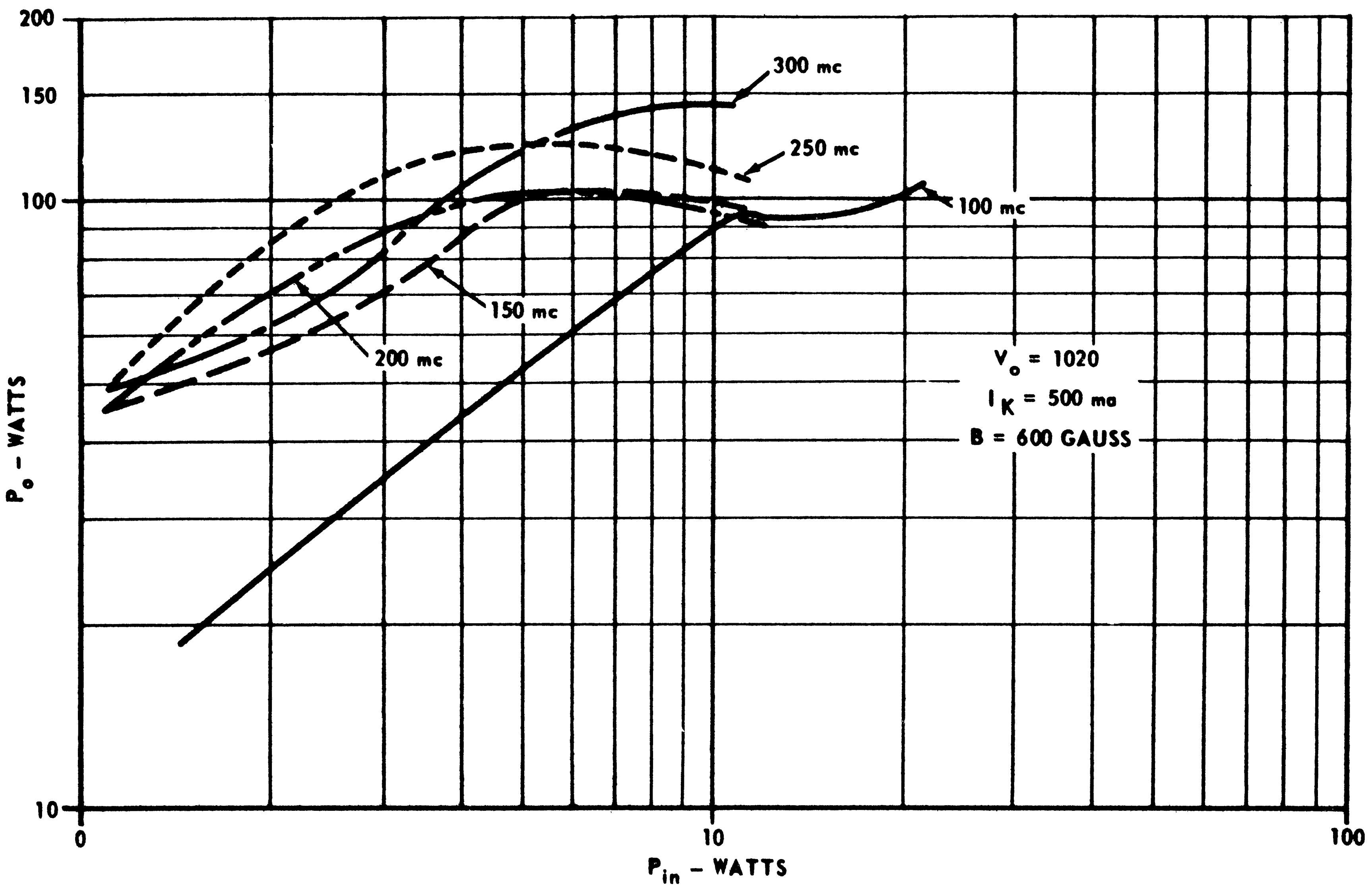

FIG. 3.3 POWER OUTPUT VS. POWER INPUT BEFORE ENVIRONMENTAL TESTS; TW-148-3R.

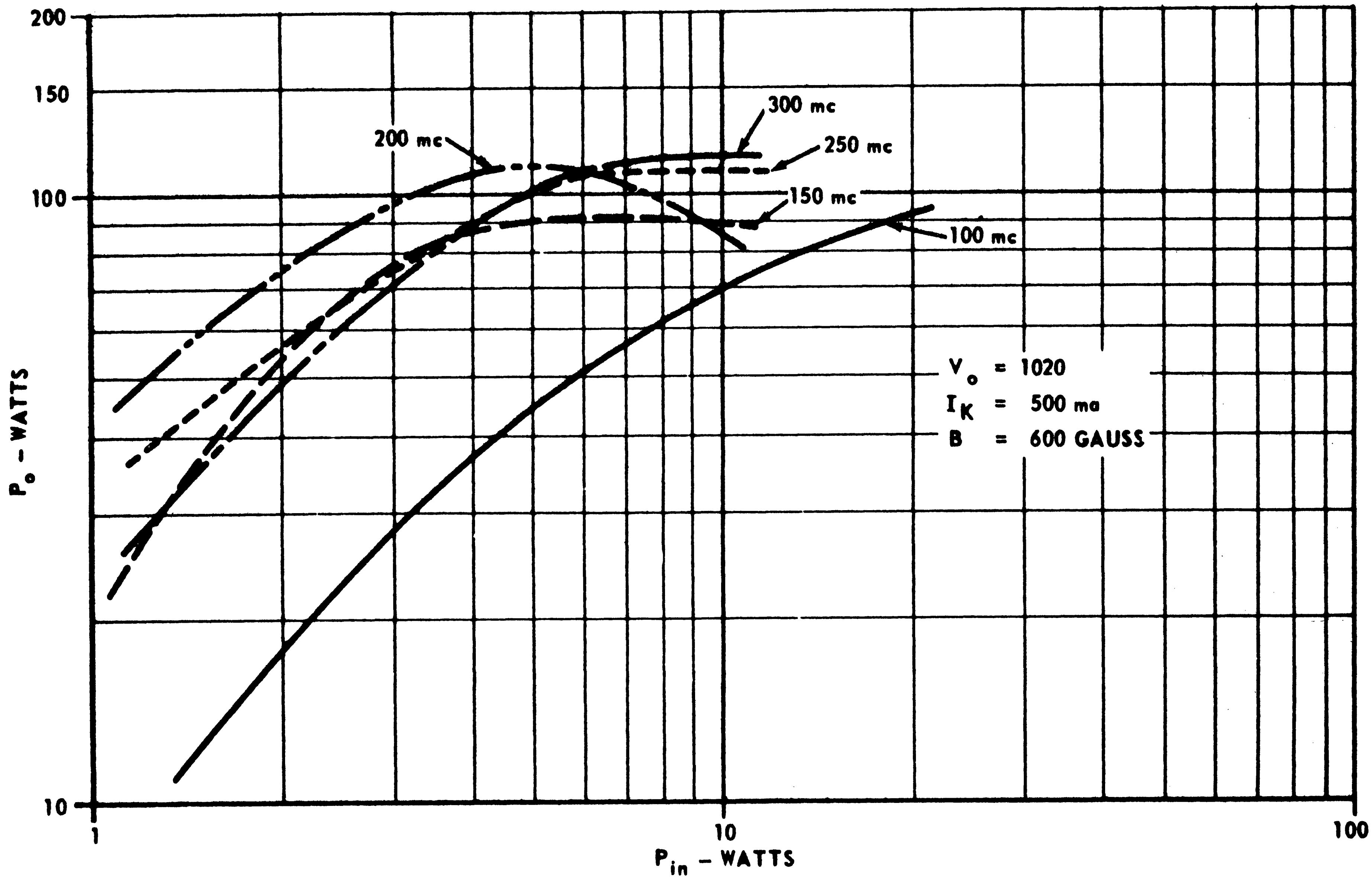

FIG. 3.4 POWER OUTPUT VS. POWER INPUT AFTER VIBRATION; TW-148-3R.

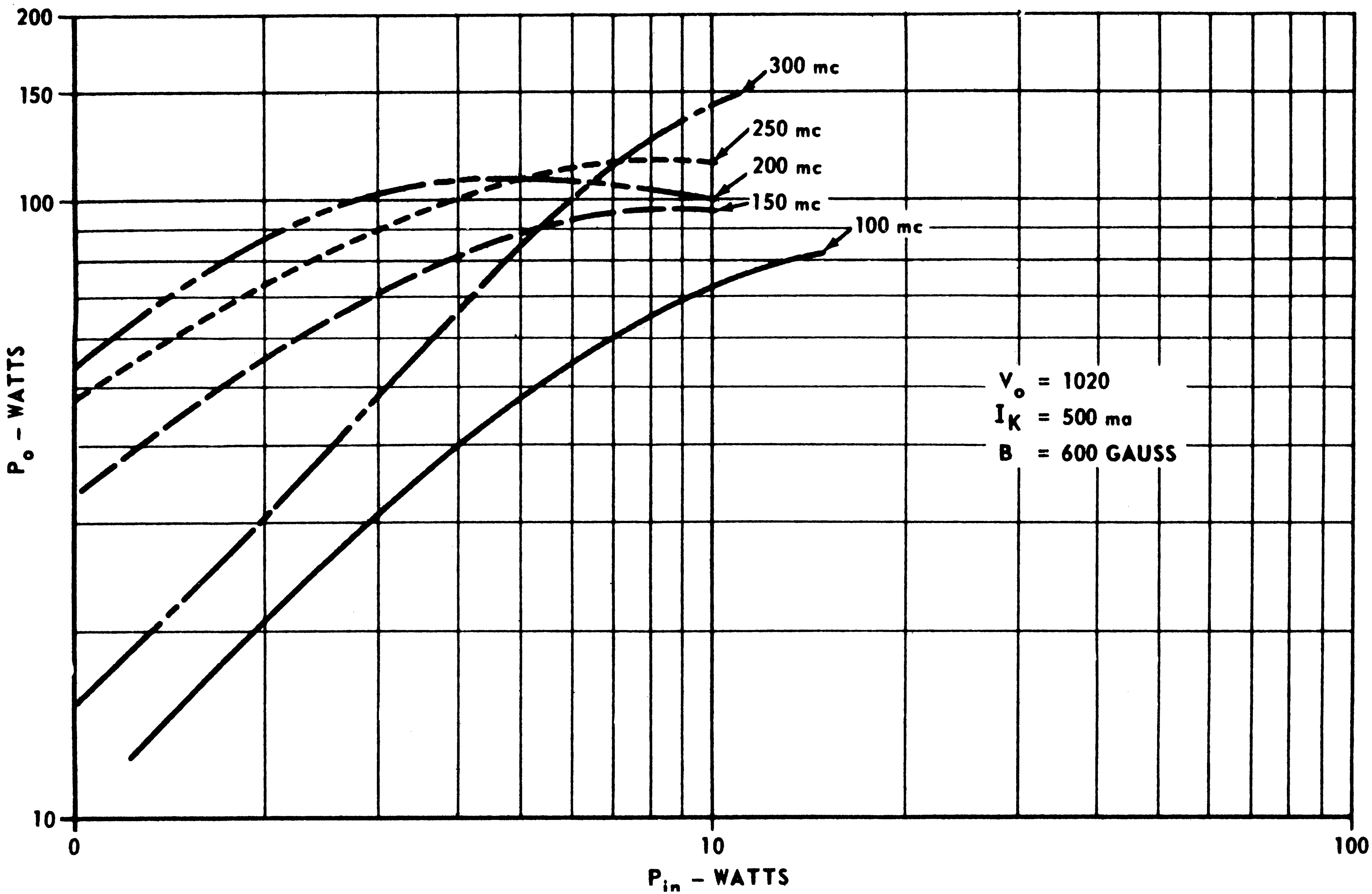

FIG. 3.5 POWER OUTPUT VS. POWER INPUT AFTER VIBRATION AND SHOCK TESTS; TW-148-3R.

Figure 3.6 is a plot of the power output vs. frequency with a 10-watt input drive signal for the three measurements discussed above. Figure 3.7 shows a plot of the maximum power output vs. frequency as obtained by using optimum input signals for each frequency.

3.5 Electron Gun. Although the two-anode gun performed satisfactorily, a one-anode gun was assembled and tested in Tube No. 3. This tube was designated TW-148-3RR. This one-anode gun provided r-f performance equivalent to that obtained with the two-anode gun. Thus, in the interest of simplicity, subsequent tubes will contain one-anode guns.

3.6 Focusing Systems. As was reported previously the magnetic field provided by the laboratory solenoid was not uniform in the gun region. A magnetic shunt was made which corrected this deficiency. Tube No. 3RR was then retested to determine the amount of change in r-f performance. These tests showed that only small changes in the r-f performance occurred, with less interception on the anode and slightly more interception on the helix.

A magnet weight of 8 to 10 pounds was forecast based on a 400 gauss magnetic field and the short length of TW-148-2. However, the tubes operating in the laboratory have performed best when the magnetic field strength is at or above 500 gauss. A new weight of 15 pounds has been calculated for a straight permanent magnet capable of providing 500 gauss over the new required length. Quotations from outside vendors, have been requested.

4. Summary and Future Work (G. T. Konrad)

The larger of the $P_\mu = 20$ guns designed by use of the digital computer programs for electrostatically focused beams and described in previous reports was constructed and tested in the beam analyzer. The

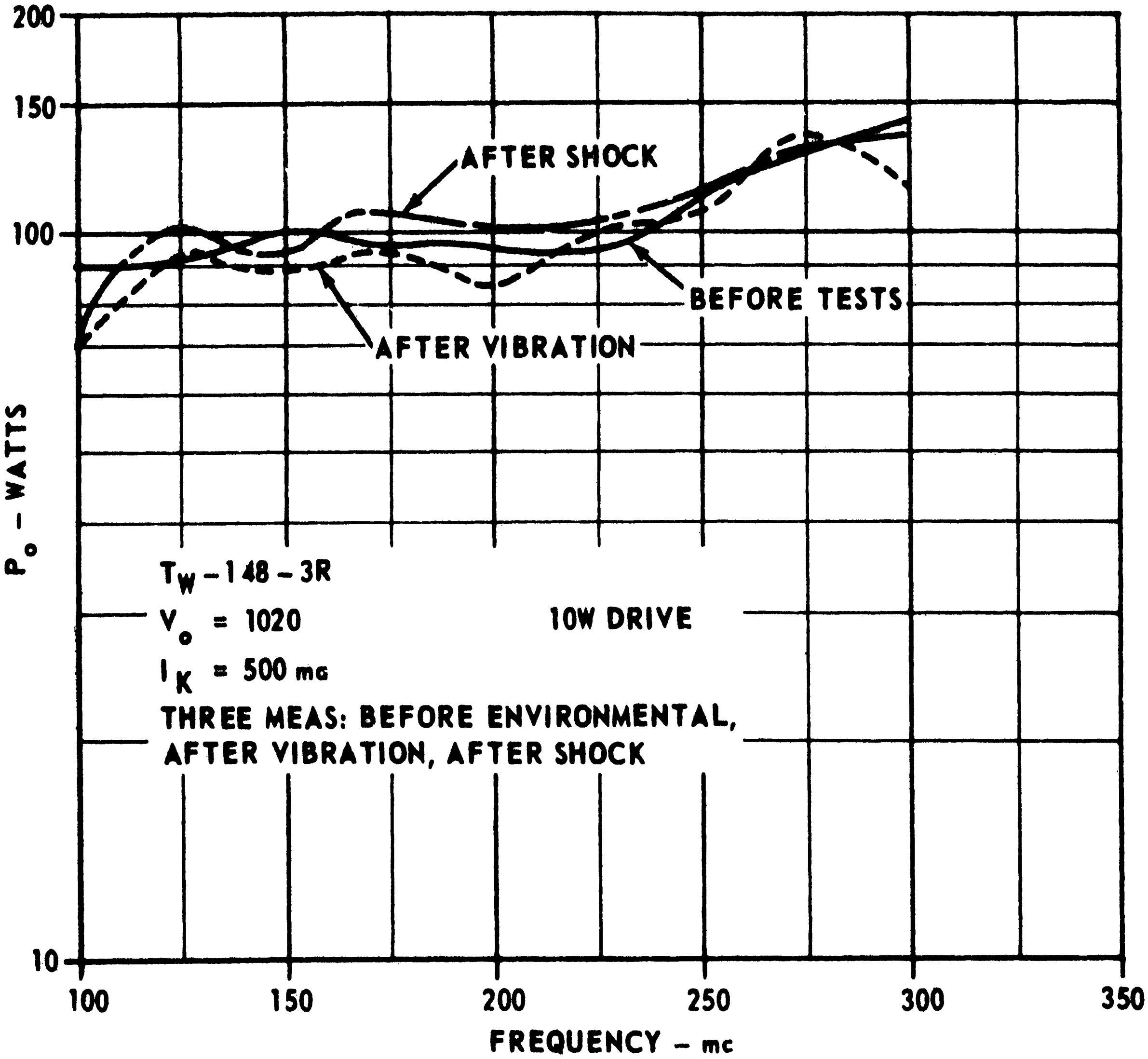

FIG. 3.6 POWER OUTPUT VS. FREQUENCY AT 10-WATTS DRIVE; TW-148-3R.

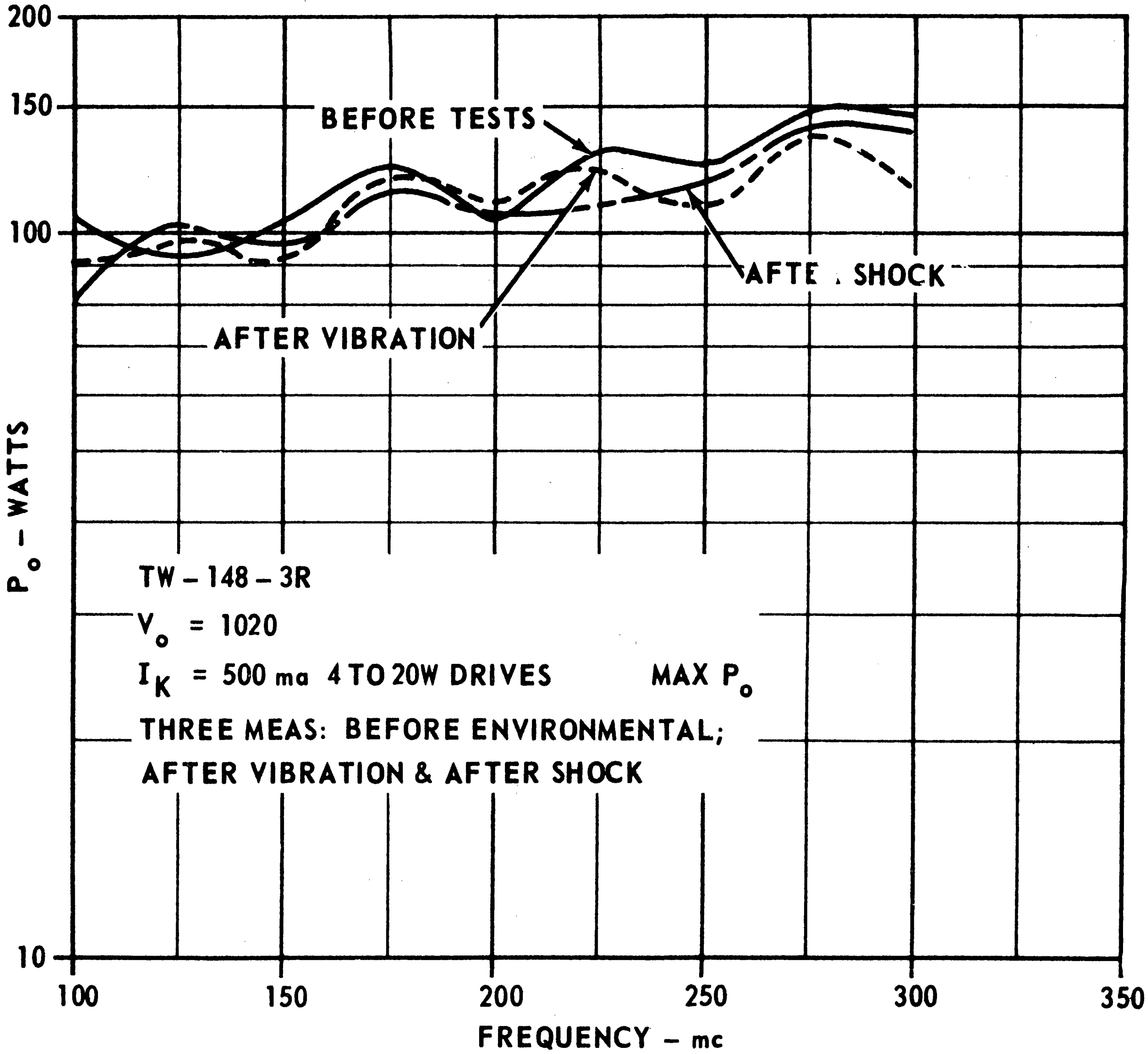

FIG. 3.7 MAXIMUM POWER OUTPUT VS. FREQUENCY--OPTIMUM DRIVE POWER; TW-148-3R.

beam configuration appears to be satisfactory, but another test is planned for the next quarter. It is hoped that some of the difficulties encountered in the tests described in this report can be overcome by replacing the cathode and repairing the beam analyzer.

The preliminary environmental tests made on the 100-watt vhf tube appear to be satisfactory. No appreciable changes in tube performance were noted as a result of these tests. Thus several more tubes will be built during the coming quarter, final environmental tests will be run and three final model tubes will be delivered in accordance with contractual requirements.

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The data obtained in a beam analyzer on a $P_{\mu} = 20$ hollow-beam electron gun is presented. Certain defects in the gun as well as the beam analyzer require that these data be redone.

The final model of the 100-watt Crestatrons to be constructed on this program is described. Performance data and the required environmental tests were obtained and are summarized in this report. On the basis of these results construction of the three final tubes appears to be warranted.

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