

AD-A058 608

HUGHES AIRCRAFT CO TORRANCE CALIF ELECTRON DYNAMICS DIV F/G 9/1  
LINEAR 1 KW MULTITONE TROPOSCATTER TWT.(U)  
AUG 78 A L ROUSSEAU

DAAB07-77-C-2713

UNCLASSIFIED

EDD-W-07564

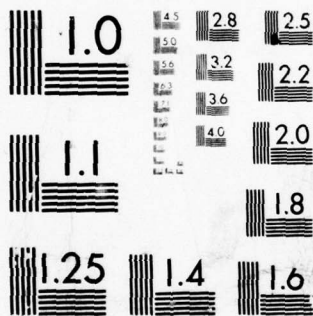
DELET-TR-77-2713-2

NL

| OF |

AD  
A058 608





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



**LEVEL III**

12

AD AO 58608

DDC FILE COPY

**Research and Development Technical Report**

DELET-TR-77-2713-2 ✓

AD 55 667

**LINEAR 1 kW MULTITONE TROPOSCATTER TWT**

**A. L. ROUSSEAU**

**HUGHES AIRCRAFT COMPANY**  
Electron Dynamics Division  
3100 West Lomita Boulevard ✓  
Torrance, California 90509

**DDC**  
**RECEIVED**  
SEP 14 1978  
**REGISTERED**  
F

**August 1978**

**Interim Report for Period 1 January 1978 - 31 April 1978**

**Approved for Public Release: Distribution Unlimited.**

**Prepared For: Electronics Technology and Devices Laboratory**

**ERADCOM**

**US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND  
FORT MONMOUTH, NEW JERSEY 07703**

**78 09 13 021**

## NOTICES

### Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

### Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| 19 REPORT DOCUMENTATION PAGE  |  | READ INSTRUCTIONS<br>BEFORE COMPLETING FORM   |
|---|--|---|
| 1. REPORT NUMBER<br>18 DELET-TR-77-2713-2   | 2. GOVT ACCESSION NO.  | 3. RECIPIENT'S CATALOG NUMBER   |
| 4. TITLE (and Subtitle)<br>6 LINEAR 1 kW MULTITONE TROPOSCATTER TWT   | 5. TYPE OF REPORT & PERIOD COVERED<br>9 Interim Report, no. 2,<br>1 Jan -31 Apr 78     | 6. PERFORMING ORG. REPORT NUMBER<br>14 EDD -W-07564   |
| 7. AUTHOR(s)<br>10 A. L. /Rousseau  | 8. CONTRACT OR GRANT NUMBER(s)<br>15 DAAB07-77-C-2713                                  | 9. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>17 B1   |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Hughes Aircraft Company<br>Electron Dynamics Division<br>3100 West Lomita Boulevard, Torrance, CA 90509<br>402 638   | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>16 IL7 62705 AH94-B1-12 | 11. CONTROLLING OFFICE NAME AND ADDRESS<br>US Army Electronics Research & Development Command<br>ET&D Laboratory, ATTN: DELET-BM<br>Fort Monmouth, New Jersey 07703 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>US Army Electronics Research & Development Command<br>ET&D Laboratory, ATTN: DELET-BM<br>Fort Monmouth, New Jersey 07703   | 12. REPORT DATE<br>Aug 1978  | 13. NUMBER OF PAGES<br>27   |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)   | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED<br>12/30                          | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE  |
| 16. DISTRIBUTION STATEMENT (of this Report)<br>Approved for Public Release<br>Distribution Unlimited  |  |   |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)  |  |   |
| 18. SUPPLEMENTARY NOTES   |  |   |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>High Power TWT<br>Intermodulation Distortion<br>Depressed Collector<br>High Efficiency Tube   |  |   |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This report covers the second triannual effort of a Research and Development program to design, construct, and test an advanced, high efficiency traveling-wave tube designed to amplify multiple signals while minimizing any mixing products which result from non-linear operation. The tube will be operated in the linear region below saturation; tube efficiency will be enhanced by means of a four stage depressed collector. |  |   |

(continued)

UNCLASSIFIED

402 638

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. During the report period the scaled electron gun was constructed and evaluated in the demountable beam analyzer. The detail mechanical design for the gun to be used in the tube was completed. Parts were ordered.

Phase shift measurements of the RF circuit were completed. Circuit parts for the tube were ordered.

The mechanical design of the four stage collector was continued. Thermal analysis led to a change in the electrode configuration to handle the high power densities.

Design of the overall packaging was started.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PURPOSE

The purpose of this program is to design, construct, and test an advanced high efficiency traveling-wave tube in accordance with U.S. Army Electronics Command, Beam, Plasma and Display Technical Area Guidelines "MW-114 for the Linear 1 kW Multitone Troposcatter Traveling Wave Tube". dated 20 October 1976. This tube will be designed to amplify multiple signals while minimizing any mixing products which result from non-linear operation. It will operate at a power output of 1.0 kW CW with a gain of 40 dB over the 4.4 to 5.0 GHz frequency band. It will be operated in the linear region below saturation. Overall tube efficiency will be enhanced by means of a multiple stage depressed collector. The tube will use a coupled-cavity interaction circuit with integral permanent magnet beam focusing. Air cooling is an objective.

The program calls for the delivery of one exploratory developmental model representative of the work accomplished under the development effort. The length of the program is twelve months.

|                                 |              |                                     |
|---------------------------------|--------------|-------------------------------------|
| ACCESSION for                   |              |                                     |
| NTIS                            | Wide Section | <input checked="" type="checkbox"/> |
| DDC                             | Buff Section | <input type="checkbox"/>            |
| UNANNOUNCED                     |              | <input type="checkbox"/>            |
| JUSTIFICATION                   |              |                                     |
| BY                              |              |                                     |
| DISTRIBUTION/AVAILABILITY CODES |              |                                     |
| Dist.                           | AVAIL        | SPECIAL                             |
| A                               |              |                                     |

78 09 13 021

## TABLE OF CONTENTS

| <u>Section</u> |                       | <u>Page</u> |
|----------------|-----------------------|-------------|
| 1.0            | INTRODUCTION          | 1           |
| 2.0            | ELECTRON GUN          | 5           |
| 3.0            | INTERACTION CIRCUIT   | 11          |
| 4.0            | COLLECTOR AND PACKAGE | 14          |
| 5.0            | PLANS FOR NEXT PERIOD | 19          |

LIST OF ILLUSTRATIONS

| <u>Figure</u> |  | <u>Page</u> |
|---------------|--|-------------|
| 1             | Test diode.  | 6           |
| 2             | 238A demountable guns $V_b$ vs $r$ 1/20.   | 7           |
| 3             | 238B isolated anode electron gun.  | 9           |
| 4             | 673H cavity dimensions.  | 12          |
| 5             | Measured frequency vs phase ( $\omega\beta$ ) characteristic of interaction circuit. | 13          |
| 6             | Layout of four-stage depressed collector for the 673H.                               | 15          |
| 7             | Schematic layout of present four-stage depressed collector for 673H.                 | 17          |

## 1.0 INTRODUCTION

The basic objective of the present program is to demonstrate an optimum traveling-wave tube (TWT) design for applications in tactical troposcatter communications systems. The design of this tube will be based on the data presented in the Research and Development Technical Report ECOM-75-1283-F. The primary design concept is to operate the tube below saturation in order to achieve the low intermodulation (IM) requirements. To achieve the required performance characteristics the tube will be operated approximately 6 to 7 dB below saturation. At the rated power of 1.0 kW minimum, the basic efficiency of the tube will be approximately 4 percent. To improve the overall efficiency of the tube, a four-stage depressed collector will be used to recover most of the kinetic energy in the spent beam. The original design study indicated that the overall efficiency can be increased to a minimum of 25 percent by using this technique.

The specification for the multitone troposcatter TWT is presented in Table I.

Periodic permanent magnet (PPM) focusing of the electron beam and air cooling are objectives of the tube design because the overall efficiency will be greater if PPM focusing is used in place of conventional solenoid focusing with the attendant solenoid power supply and air cooling will make the tube more compatible with existing troposcatter transmitters. Therefore, these features are being used for the multitone tube.

The theoretical electrical characteristics of the tube were described in detail in the earlier report, ECOM-75-1283-F. The purpose of the present program is to construct a tube having the previously determined

TABLE 1  
SPECIFICATION FOR MULTITONE TROPOSCATTER TWT 673H

|                                  |  |
|----------------------------------|--|
| <u>Electrical Requirements:</u>  |  |
| Frequency Range                  | 4.4 - 5.0 GHz (Min)                                |
| Power Output (CW)                | 1 kW (Min)   |
| Gain                             | 40 dB (Min)  |
| Instantaneous Bandwidth (-1 dB)  | 15 MHz (Min)                                       |
| Beam Voltage                     | -26 kV (Max)                                       |
| Beam Current                     | 1.5 A (Max)  |
| Efficiency (Note 1)              | 25% (Min)  |
| Intermodulation (Note 2)         | -20 dBC  |
| Output Load VSWR                 | 1.5:1 Max  |
| Focusing                         | PPM (Objective)                                    |
| Life                             | 10,000 Hrs. (Objective)                            |
| <u>Mechanical/Environmental:</u> |  |
| Size                             | To Be Determined (TBD)                             |
| Weight                           | To Be Determined (TBD)                             |
| Cooling                          | Air (Objective)                                    |
| RF Input Connector               | Type N Coax  |
| RF Output Connector              | WR-187 Waveguide/UG-149/Flange                     |
| Altitude (Operating)             | 3,100 Meters                                       |
| Ambient Temperature (Operating)  | -50°C to 55°C                                      |
| Mounting (Operating)             | 0 to 15° from Vertical                             |
| Shock (Non-operating)            | 50 G, 1 msec                                       |
| Vibration (Non-operating)        | 5 to 55 Hz<br>1.02 cm Amplitude<br>5 ± 0.5 Minutes |

Note:

1. The overall TWT efficiency is defined as:  
RF output power divided by the sum of beam input power, cooling power, focusing power, and heater power. The tube shall be capable of meeting the efficiency specified under conditions where the IM products are within the specified limits with 4 to 16 signals applied to the input.
2. The intermodulation products requirement will be met over any 15 MHz band in the 4.4 GHz to 5 GHz frequency range. The 15 MHz band will be divided into sixteen adjacent equal bandwidth channels. Anywhere from 4 to 16 of the channels will be occupied by carriers. The total intermodulation power in any occupied channel shall be 20 dB below the carrier in that channel. The carrier output power of all the occupied channels shall total 1 kW.

design parameters and measure its operating performance. This effort consists chiefly of the following areas:

1. An electron gun will be scaled to the required beam size, area convergence, and perveance and mounted in an existing isolated anode support structure.
2. The RF intereaction circuit and integral PPM focusing structure will be designed. This includes determining the final circuit dimensions to give the required phase shift characteristics, providing adequate circuit loss for stability, and matching the circuit to internal sever terminations, an input coaxial coupler, and an output waveguide step transformer and window.
3. The mechanical design of the four-stage depressed collector will be accomplished, taking into account the voltage standoff and thermal dissipation requirements, using the electrode configuration that had been determined previously.
4. The overall packaging and cooling structure of the tube will be designed.
5. The experimental tube will be fabricated and tested.

During the second triannual period of the program the scaled electron gun was evaluated in the demountable beam tester, the mechanical design of the electron gun was completed, and parts for the gun to be used on the tube were ordered. The phase shift and impedance measurements were completed to establish the RF circuit configuration and circuit parts for the tube were ordered.

The mechanical design of the collector was continued. A considerable amount of effort and redesign were directed to this area as a result of the thermal calculations, which indicated that over heating and excessive mechanical stress could occur as a result of the high beam power densities.

## 2.0 ELECTRON GUN

The basic electrical design of the 238B electron gun was described in the first Triannual Interim report. The design parameters are summarized in Table II. During the present report period a scaled version of the gun was evaluated in the demountable beam analyzer. This gun, designated the 238A, was scaled from the 238B by a factor of 0.911 in order to obtain a scaled cathode diameter of 0.440 inch (11.18 mm), which is compatible with the analyzer test fixtures. A photograph of the test setup is shown in Figure 1.

Two versions of the 238A gun were checked differing only in cathode to anode spacing. The 238A gun number 1 had a measured perveance of 0.30 micropervs rather than the design perveance of 0.33 micropervs.

The cathode to anode spacing was then decreased by 0.010 inch. The measured perveance of this 238A gun number 2 was 0.33 micropervs. The beam minimum occurs 1.432 inches (36.37 mm) from the cathode valley. The measured  $r_{1/20}$  is 0.040 inch (1.02 mm) at 10 kV. ( $r_{1/20}$  is the beam radius where the current density is 1/20 the peak current density.) 10 kV is the maximum test voltage that can be used with the demountable analyzer. The predicated  $r_{1/20}$  at an operating voltage of 25 kV is 0.0355 inch (0.902 mm). A plot of beam voltage versus  $r_{1/20}$  is shown in Figure 2.

The final 238B gun design was obtained by scaling the dimensions of the 238A gun number 2 by 1.0977. The relevant theoretical and experimental gun parameters are summarized in Table III. ( $r_{99.5}$  is the radius of the envelope containing 99.5 percent of the beam current.)

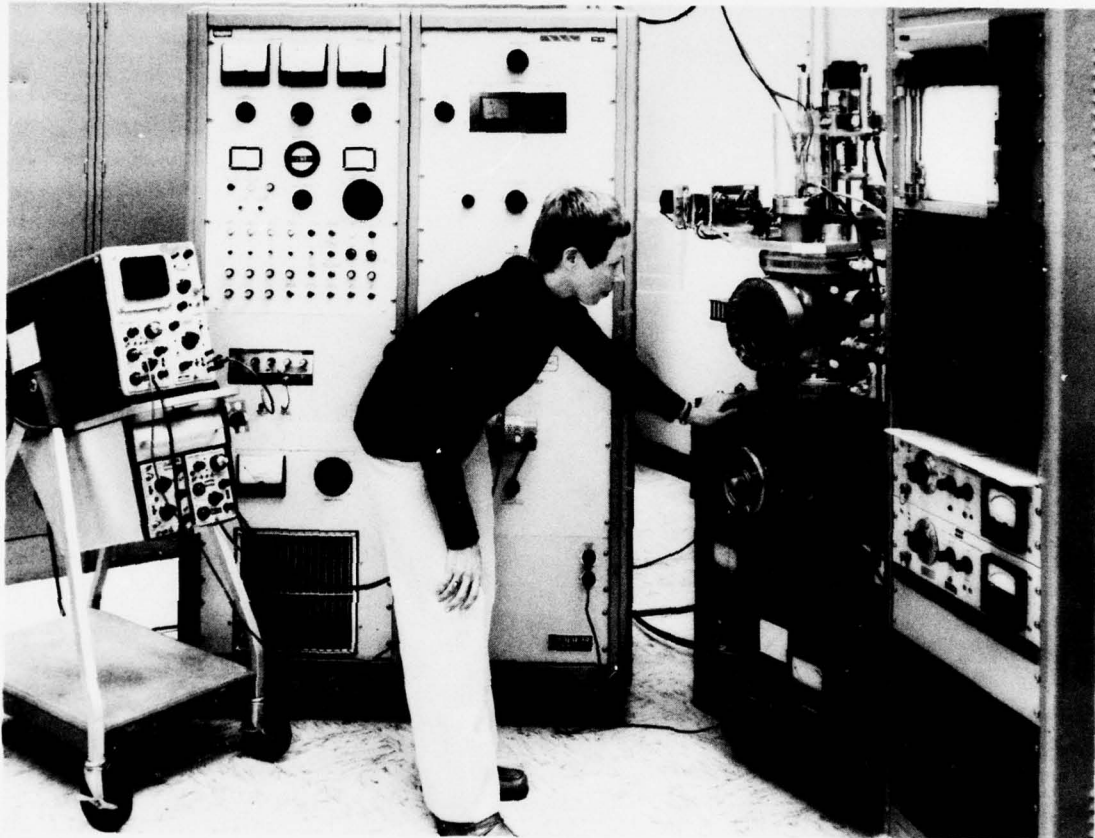


Figure 1 Electrostatic demountable beam analyzer.

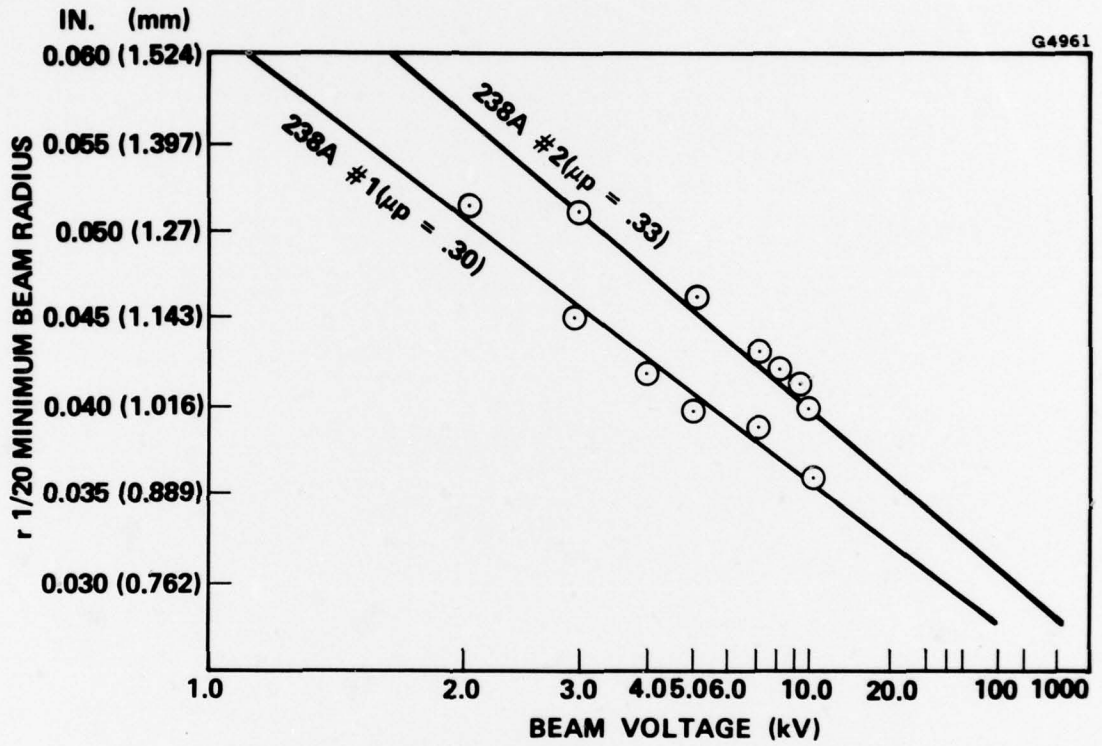


Figure 2 238A demountable guns  $V_b$  vs  $r 1/20$ .

TABLE II  
238B ELECTRON GUN DESIGN PARAMETERS

|                       |                       |
|-----------------------|-----------------------|
| Cathode Voltage       | -25 kV                |
| Cathode Current       | 1.3 A                 |
| Perveance             | $0.33 \times 10^{-6}$ |
| Cathode Loading       | $1.1 \text{ A/cm}^2$  |
| Nominal Beam Diameter | 0.121 inch (3.07 mm)  |
| Area Compression      | 16:1                  |
| Cathode Material      | Impregnated tungsten  |
| Magnetic Field        | PPM                   |
| Magnetic Period       | 1.036 inch (26.31 mm) |

The detail mechanical design of the 238B gun was completed. This involved adapting the 238B electrodes to a standard isolated anode insulator assembly with appropriate corrections to account for the differential expansions of the various support elements of the gun at operating temperature. The gun layout is shown in Figure 3.

Parts for the gun that will be used on the tube have been ordered. The design of the assembly fixtures has been started. Construction of the gun will be started in June.

G5039

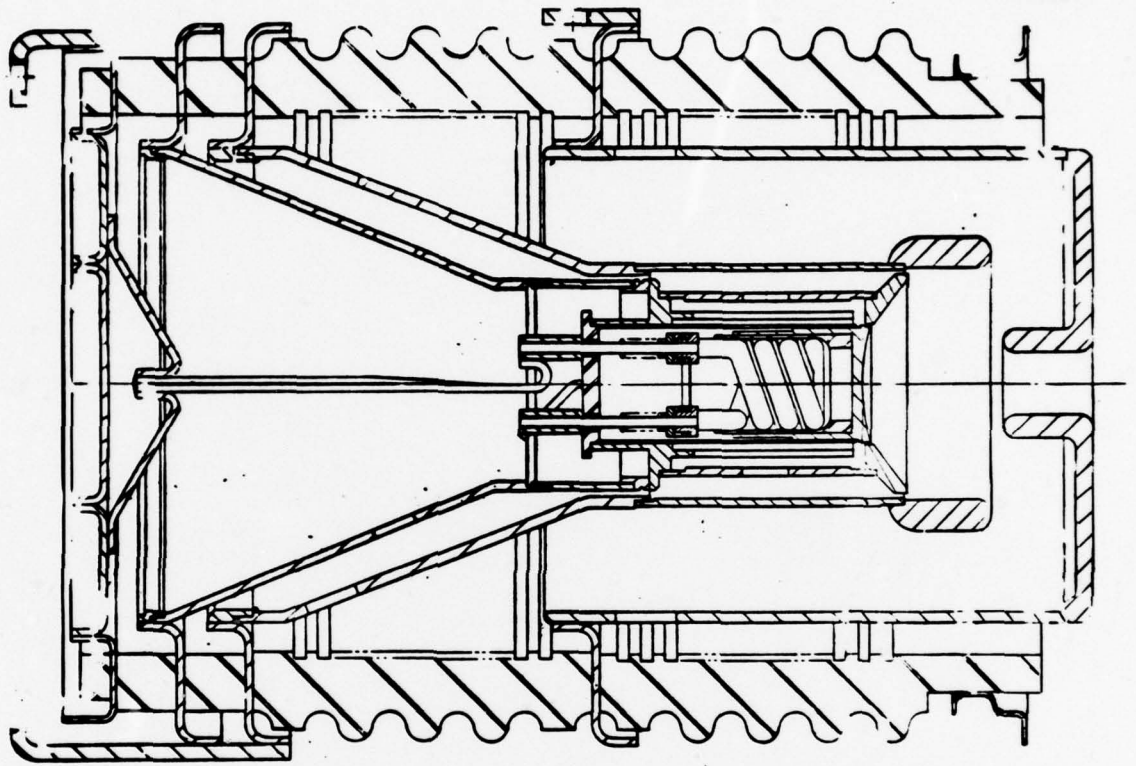


Figure 3 238B isolated anode electron gun.

TABLE III  
SUMMARY OF THEORETICAL AND EXPERIMENTAL 238 GUN PARAMETERS

|  | 238B<br>Design           | 238A<br>Number 2<br>Test | 238B<br>Design           | 238B<br>"A" Scaled       |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| Perveance<br>(micropervs)                                      | 0.33                     | 0.33                     | 0.33                     | 0.33                     |
| $r_{1/20}$<br>Electrostatic<br>at 25 kV<br><u>inch</u><br>(mm) | $\frac{0.0357}{(0.907)}$ | $\frac{0.0328}{(0.833)}$ | $\frac{0.0392}{(0.996)}$ | $\frac{0.0360}{(0.914)}$ |
| $r_{99.5}$<br>Focused<br>at 25 kV<br><u>inch</u><br>(mm)       | $\frac{0.0725}{(1.842)}$ | $\frac{0.0666}{(1.692)}$ | $\frac{0.0796}{(2.022)}$ | $\frac{0.0731}{(1.857)}$ |
| Cathode valley<br>to Beam Min.<br>inches (mm)                  | $\frac{1.45}{(36.83)}$   | $\frac{1.43}{(36.32)}$   | $\frac{1.59}{(40.39)}$   | $\frac{1.57}{(39.88)}$   |

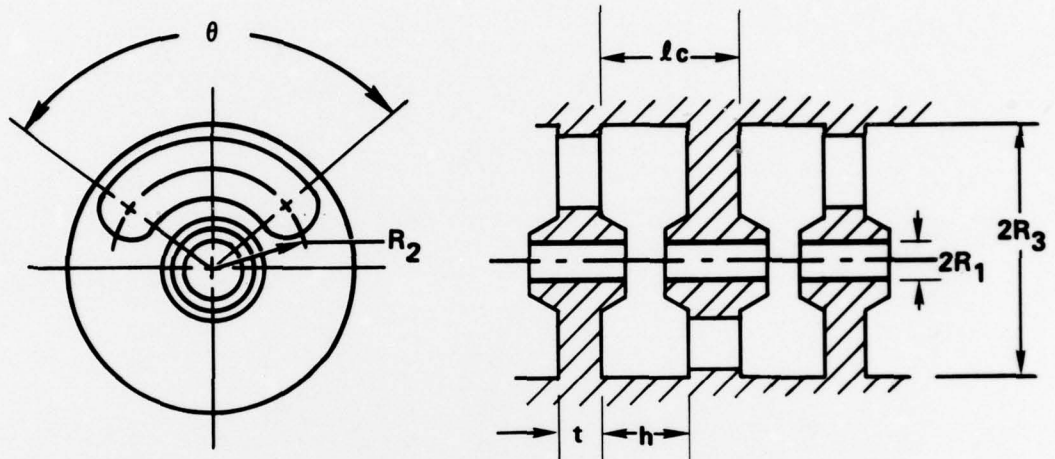
### 3.0 INTERACTION CIRCUIT

The basic circuit parameters for the 673H were chosen in the previous study program. During the present report period, phase shift measurements were made on experimental cold test circuit structures to obtain the exact circuit dimensions. In these measurements the drift tube ferrule gap and the size of the coupling hole are varied until the desired pass band has been obtained. Resonant loss material was included in these cold test circuits to properly simulate the actual tube circuit. (The loss material lowers the pass band by about 250 MHz). The final dimensions are shown in Figure 4.

The measured phase-vs-frequency ( $\omega$ - $\beta$ ) characteristic for this circuit is presented in Figure 5.

Frequency perturbation measurements with a dielectric rod were made to determine the circuit interaction impedance. The small signal gain was then calculated taking into account the measured circuit impedance and electron beam characteristics. These calculations indicated that the gain will be approximately 0.1 dB per cavity higher than had been assumed in the original study. The circuit configuration has, therefore, been chosen to have 16 cavities in the driver section and 17 cavities in the output section, not including termination and matching cavities.

Cold test fixtures have been designed and fabricated. They will be used in matching the circuit to the internal sever terminations and to the external waveguide. The other circuit parts have been ordered. The pacing items are the pole pieces, which are laminations of copper and iron to improve the thermal capability. The iron-copper pole piece blanks have been brazed. They are out for final machining to the dimensions determined by the cold test measurements. They are due back in May. When they are received, the final matching and assembly of the tube circuit will be started.



$2R_1 = 0.202 \text{ in. (5.13 mm)}$   
 $R_2 = 0.385 \text{ in. (9.78 mm)}$   
 $2R_3 = 1.100 \text{ in. (27.94 mm)}$

$l_c = 0.518 \text{ in. (13.16 mm)}$   
 $h = 0.400 \text{ in. (10.16 mm)}$   
 $t = 0.118 \text{ in. (3.00 mm)}$   
 $\theta = 110^\circ$

Figure 4 673H cavity dimensions.

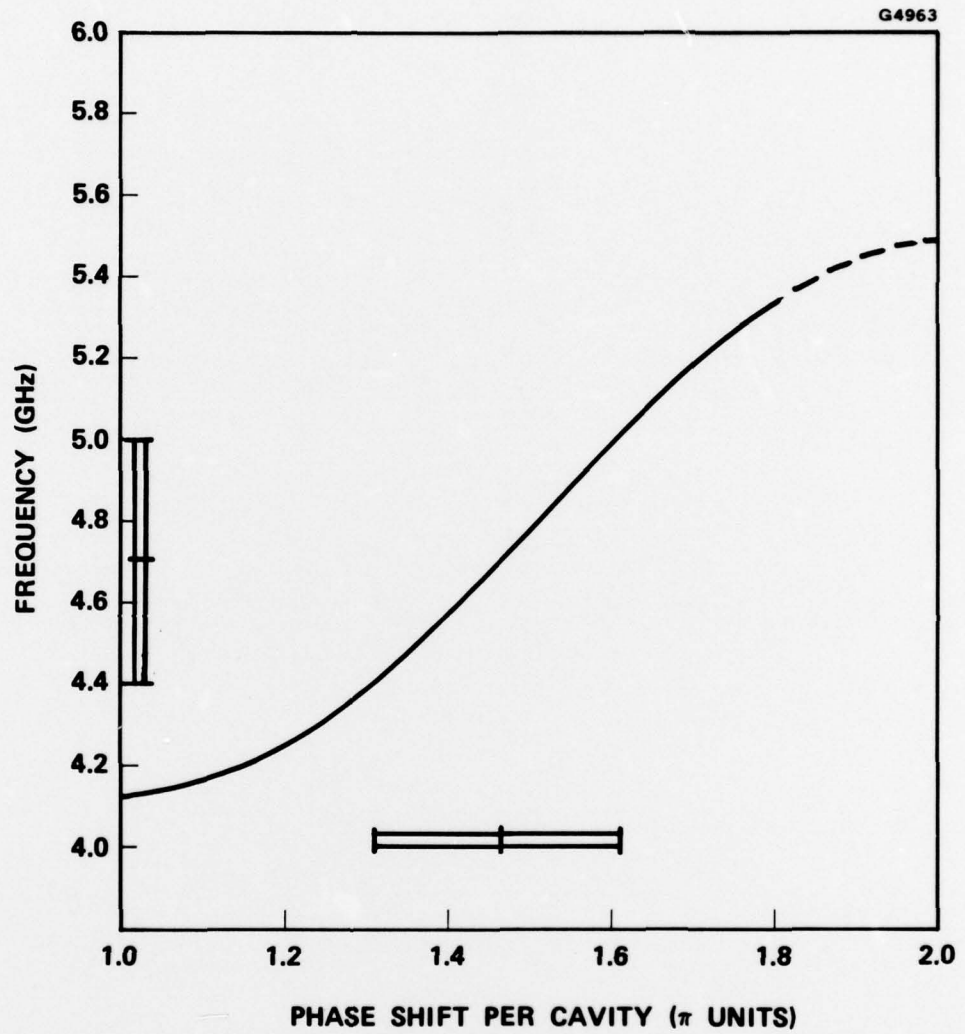


Figure 5 Measured frequency vs phase ( $\omega\beta$ ) characteristic of interaction circuit.

#### 4.0 COLLECTOR AND PACKAGE

As described in the last report, the four-stage depressed collector is a crucial element in achieving high overall efficiency on the 673H. The optimization of the shapes and depression voltages for each electrode was performed during the previous study program. The detail mechanical design is being done on the present program. Because of the large power dissipation and the fairly high electrode voltages required by the electrical design, the thermal and mechanical design of the collector has become the most complex and critical portion of the 673H program.

The primary design criteria for this collector is to provide the electrical standoff for the four electrodes and at the same time provide a good thermal path out to the air-cooled fins. To achieve these requirements the electrodes will be completely enclosed within a ceramic cylinder. This ceramic will provide both electrical isolation and thermal conduction in the radial direction for the collector elements. Using this technique, the electrical standoff for the collector is located within the vacuum envelope, eliminating the possibility of externally contaminating the insulator surface. The electrical connections are made through conventional high voltage feed throughs.

A preliminary layout of the initial concept of the collector design is shown in Figure 6. The individual electrodes are brazed to metalized bands on the inside of the ceramic cylinder. The electrodes are thin to relieve the stresses due to the differential thermal expansions between the copper electrodes and the alumina ceramic. The feed throughs are located in a separate weld ring located at the front of the collector near the output pole piece. This arrangement results in the shortest lengths of the connecting leads. The cooling fins could be either brazed or clamped to the outside of the metalized ceramic cylinder.

G4500

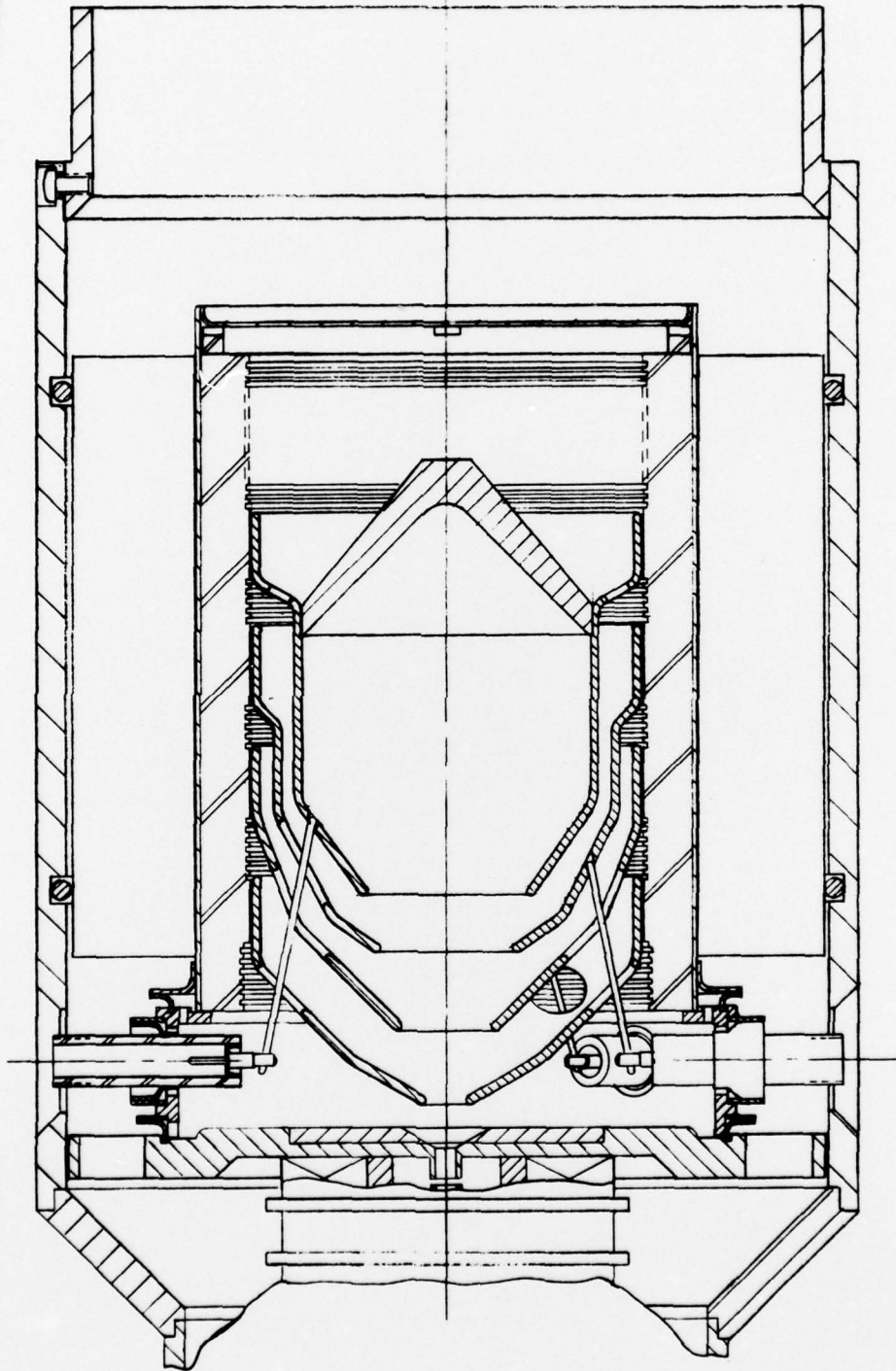


Figure 6 Layout of four-stage depressed collector for the 673H.

Drawings of detail parts were started for this initial collector configuration. However, when the thermal calculations were made for the maximum expected incident beam power, it was found that the temperature rise from the ceramic wall to the snout of the electrode would be about  $1300^{\circ}\text{C}$ , even though copper is an excellent conductor. This was entirely too high.

Therefore, the layout of the collector was modified to make the electrodes as thick as possible in the axial direction and as short as possible in the radial direction, while maintaining the shapes of the snouts of the electrodes required for good electrical performance. This necessitated running the feed throughs out at the back end of the collector. A layout of this arrangement is shown in Figure 7. Because the spacing for the leads is tighter with the feed throughs at the back, the leads will be enclosed in ceramic tubing for extra insulation. The shape of the large ceramic cylinder has been modified to accommodate this new configuration. (This did not affect the schedule appreciably because the ceramics that were on order had not yet been machined.)

It is planned that the electrodes, leads, weld flanges, and cooling fins will be attached to the ceramic insulator in a one-shot braze. The assembly fixturing is being planned accordingly.

The power distribution on the various collector electrodes will vary depending on the particular operating condition. The thermal calculations were made assuming the worst expected case for each electrode. With the present collector configuration the highest calculated electrode temperature is  $428^{\circ}\text{C}$ , which occurs on the third electrode from the output pole piece. The assumptions were an inlet air temperature of  $38^{\circ}\text{C}$  with an air flow of 400 CFM. The maximum total collector input power will be 4.8 kW with a maximum power to the third electrode 2.2 kW. The collector

G4964

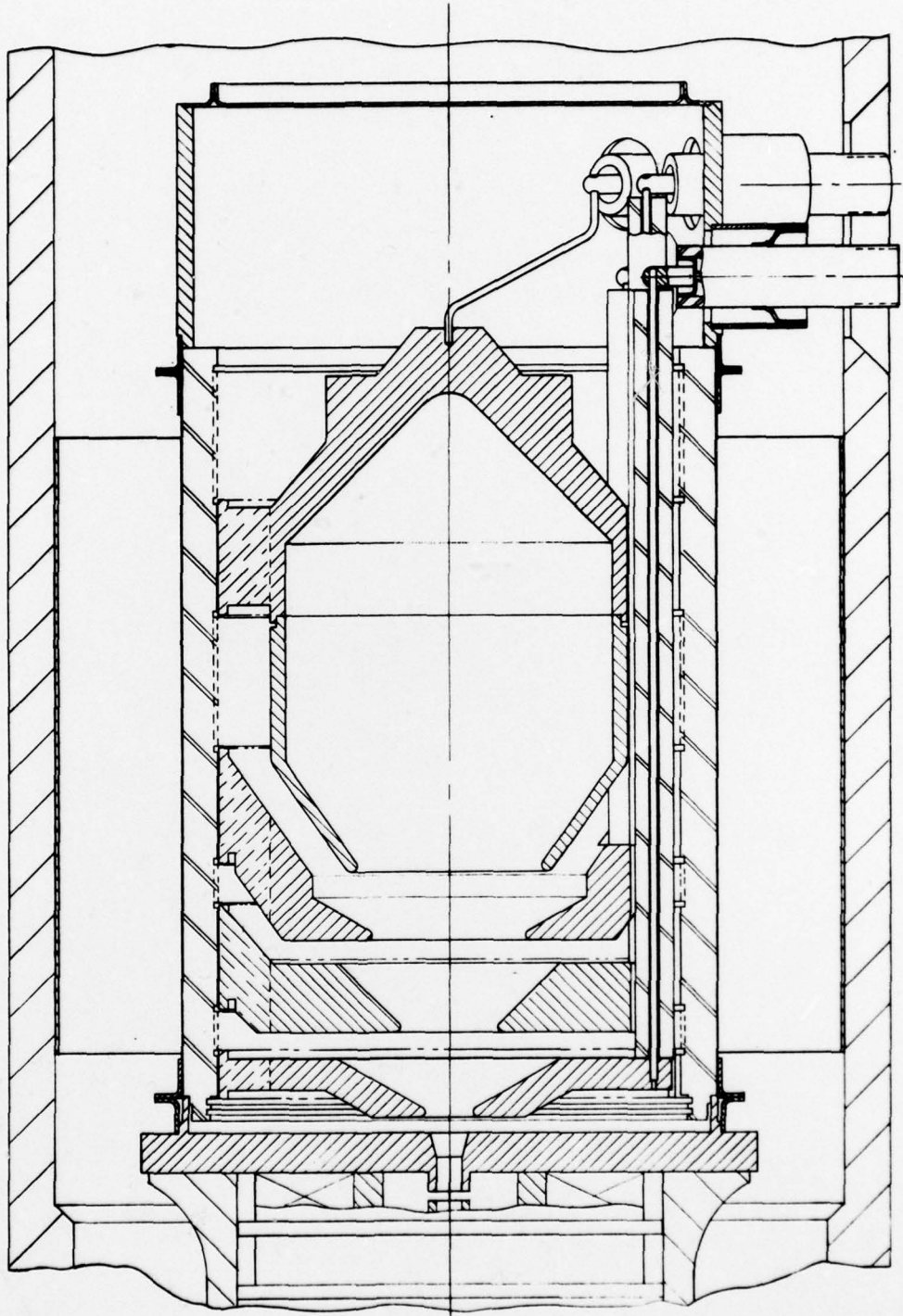


Figure 7 Schematic layout of present four-stage depressed collector for 673H.

fins will be brazed to the ceramic. The calculations take into account the fact that the air through several of the fins will be blocked by the output waveguide. Based on these results, the present design should meet the collector requirements.

The design of the overall tube package was continued. The details of the package will be finalized after the detail design of the collector has been completed.

## 5.0 PLANS FOR NEXT PERIOD

1. The design of the fixtures for the 238A isolated anode electron gun will be completed. They will be ordered. The gun for the tube will be fabricated, checked in the demountable beam analyzer, and put on the 673H tube.
2. The design of the four-stage collector will be completed. A sample electrode to ceramic braze will be made and evaluated. The collector parts will be ordered. The collector assembly fixtures will be designed and ordered. The collector will be fabricated and installed on the 673H tube.
3. The matching of the RF interaction circuit to the internal terminations, coaxial input line, and output waveguide will be accomplished. The circuit will be fabricated.
4. The design of the external package will be completed. Parts will be ordered.
5. The 673H tube will be assembled, processed, and tested.

DISTRIBUTION LIST

|   | <u>No.</u><br><u>Copies</u> |   | <u>No.</u><br><u>Copies</u> |
|---|-----------------------------|---|-----------------------------|
| Defense Documentation Center<br>ATTN: DDC-TCA<br>Cameron Station (Bldg. 5)<br>Alexandria, VA 22314            | 12                          | Commander<br>Naval Electronics Laboratory Center<br>Attn: Library<br>San Diego, CA 92152                                  | 1                           |
| Code R123, Tech Library<br>DCA Defense Comm Engrg Ctr<br>1860 Wiehle Ave.<br>Reston, VA 22090                 | 1                           | CDR, Navar Surface Weapons Center<br>White Oak Laboratory<br>Attn: Library, Code WX-21<br>Silver Spring, MD 20910         | 1                           |
| Defense Communications Agency<br>Technical Library Center<br>Code 205 (P. A. Tolovi)<br>Washington, DC 20305  | 1                           | Commandant, Marine Corps<br>HQ, US Marine Corps<br>Attn: Code LMC<br>Washingto, DC 20380                                  | 2                           |
| Office of Naval Research<br>Code 427<br>Arlington, Va 22217   | 1                           | HQ, US Marine Corps<br>Attn: Code Ints<br>Washington, DC 20380  | 1                           |
| Gidep Engineering & Support Dept.<br>TE Section<br>PO Box 398<br>Norco, CA 91760                              | 1                           | Command, Control & Communications Div<br>Development Center<br>Marine Corps Development & Educ Comd<br>Quantico, VA 22134 | 1                           |
| Director<br>Naval Research Laboratory<br>Attn: Code 2627<br>Washington, DC 20375                              | 1                           | Rome Air Development Center<br>Attn: Documents Library (TILD)<br>Griffiss AFB, NY 13441                                   | 1                           |
| HQ ESD (DRI)<br>L. G. Hanscom AFB<br>Bedford, MA 01731  | 1                           | Commandant<br>US Army Military Police School<br>Attn: ATSJ-CD-M-C<br>Fort McClellan, AL 36201                             | 3                           |
| HQ, Air Force Systems Command<br>Attn: DLCA<br>Andrews AFB<br>Washington, DC 20331                            | 1                           | Commander<br>US Army Intelligence Center & School<br>Attn: ATSI-CD-MD<br>Fort Huachuca, AZ 85613                          | 2                           |
| Cdr, MIRCOM<br>Redstone Scientific Info Center<br>Attn: Chief, Document Section<br>Redstone Arsenal, AL 35809 | 1                           | Commander<br>HQ Fort Huachuca<br>Attn: Technical Reference Div<br>Fort Huachuca, AZ 85613                                 | 1                           |

|  | <u>No.</u><br><u>Copies</u> |  | <u>No.</u><br><u>Copies</u> |
|--|-----------------------------|--|-----------------------------|
| Commandant<br>US Army Aviation Center<br>Attn: ATZQ-D-MA<br>Fort Rucker, AL 36362  | 3                           | Deputy for Science & Technology<br>Office, Assist Sec Army (R&D)<br>Washington, DC 20310                 | 1                           |
| Director, Ballistic Missile Def<br>Advanced Technology Center<br>Attn: ATC-R, PO Box 1500<br>Huntsville, AL 35807              | 1                           | Director<br>US Army Material Systems Analysis Act.<br>Attn: DRXSY-T<br>Aberdeen Proving Ground, MD 21005 | 1                           |
| HODA (DAMA-ARZ-D)<br>Dr. F. D. Verderame<br>Washington, DC 20310   |                             | Commander<br>US Army Tank-Automotive Command<br>Attn: DRDTA-RH<br>Warren, MI 48090                       |                             |
| Commandant<br>US Army Signal School<br>Attn: ATSN-CTD-MS<br>Fort Gordon, GA 30905  | 1                           | CDR, US Army Aviaion Systems Command<br>Attn: DRSAV-G<br>PO Box 209<br>St. Louis, MO 63166               | 1                           |
| Director of Combat Developments<br>US Army Armor Center<br>Attn: ATZK-CD-MS<br>Fort Knox, KY 40121                             | 2                           | Commander, Picatinny Arsenal<br>Attn: SARPA-FR-S<br>Bldg. 350<br>Dover, NJ 07801                         | 2                           |
| Commandant<br>US Army Ordnance School<br>Attn: ATSL-CD-OR<br>Aberdeen Proving Ground, MD 21005                                 | 2                           | Commander<br>Picatinny Arsenal<br>Attn: SARPA-ND-A-4 (Bldg 95)<br>Dover, NJ 07801                        | 1                           |
| CDR, Harry Diamond Laboratories<br>Attn: Library<br>2800 Powder Mill Road<br>Adelphia, MD 20783                                | 1                           | Commander<br>Picatinny Arsenal<br>Attn: SARPA-TS-S 59<br>Dover, NJ 07801                                 | 1                           |
| Director<br>US Army Ballistic Research Labs<br>Attn: DRXBR-LB<br>Aberdeen Proving Ground, MD 21005                             | 1                           | Project Manager, Rembass<br>Attn: DRCPM-RBS<br>Fort Monmouth, NJ 07703                                   | 2                           |
| Harry Diamond Laboratories,<br>Dept of Army<br>Attn: DELHD-RCB (Dr. J. Nemarich)<br>2800 Powder Mill Road<br>Adelphi, MD 20783 | 1                           | Commandant<br>US Army Air Defense School<br>Attn: ATSA-CD-MC<br>Fort Bliss, TX 79916                     | 1                           |
| General Electric Company<br>Research & Development Division<br>Attn: Dr. T. Mihran<br>Schenectady, NY 12301                    | 1                           | Commander<br>US Army Nuclear Agency<br>Fort Bliss, TX 79916  | 1                           |

|  | <u>No.<br/>Copies</u> |   | <u>No.<br/>Copies</u> |
|--|-----------------------|---|-----------------------|
| Commander<br>US Army Satellite Communications<br>Attn: DRCPM-SC-5 (A. Wachtenheim)<br>Fort Monmouth, NJ 07703      | 2                     | Commander, HQ MASTER<br>Technical Information Center<br>Attn: Mrs. Ruth Reynolds<br>Fort Hood, TX 76544 | 1                     |
| TRI-TAC Office<br>Attn: TT-SEL<br>Fort Monmouth, NJ 07703  | 1                     | Commander, Darcom<br>Attn: DRCDE<br>5001 Eisenhower Ave.<br>Alexandria, VA 22333                        | 1                     |
| CDR, US Army Research Office<br>Attn: DRXRO-IP<br>PO Box 12211<br>Research Triangel Park, NC 07709                 | 1                     | CDR, US Army Signals Warfare Lab<br>Attn: DELSW-OS<br>Arlington Hall Station<br>Arlington, VA 22212     | 1                     |
| Commandant<br>US Army Inst For Military Assistance<br>Attn: ATSU-CTD-MO<br>Fort Bragg, NC 28307                    | 1                     | Commander<br>US Army Engineer Topographic Labs<br>Attn: ETL-TD-EA<br>Fort Belvoir, VA 22060             | 1                     |
| CDR, US Army Tropic Test Center<br>Attn: STETC-MO-A (Tech Library)<br>Drawer 942<br>Fort Clayton, Canal Zone 09827 | 1                     | National Bureau of Standards<br>Bldg 225, RM A-331<br>Attn: Mr. Leedy<br>Washington, DC 20231           | 1                     |
| Division Chief<br>Meterology Division<br>Counterfire Department<br>Fort Sill, OK 73503                             | 2                     | Advisory Group on Electron Devices<br>201 Varick Street, 9th Floor<br>New York, New York 10014          | 2                     |
| TACTEC<br>Ballelle Memorial Institute<br>505 King Avenue<br>Columbus, OH 43201                                     | 1                     | Plastics Tech Eval Center<br>Picatinny Arsenal, Bldg 176<br>Attn: Mr. A. M. Anzalone<br>Dover, NJ 07801 | 1                     |
| Ketron, Inc.<br>Attn: Mr. Frederick Leuppert<br>1400 Wilson Blvd, Architech Bldg<br>Arlington, VA 22209            | 2                     | Metals and Ceramics Info Center<br>Battelle<br>505 King Avenue<br>Columbus, OH 43201                    | 1                     |
| Commander<br>US Army Logistics Center<br>Attn: ATCL-MC<br>Fort Lee, VA 22801                                       | 2                     | Commander<br>US Army Communications R&D Command<br>Fort Monmouth, NJ 07703                              |                       |
| Comsat Laboratories<br>Attn: R. Strauss<br>Clarisbury, Maryland 20734  | 1                     | 1 DRDCO-COM-RO<br>1 USMC-LNO<br>1 ATFE-LO-EC  |                       |

|   | <u>No.</u><br><u>Copies</u> |  | <u>No.</u><br><u>Copies</u> |
|---|-----------------------------|--|-----------------------------|
| Director, Night Vision Laboratory<br>US Army Electronics R&D Command<br>Attn: DELNV-D<br>Fort Belvoir, VA 22060                 | 1                           | Commander<br>US Army Communications & Electronic<br>Material Readiness Command   |                             |
| CDR/DIR, Atmospheric Sciences Lab<br>US Army Electronics R&D Command<br>Attn: DELAS-SY-S<br>White Sands Missile Range, NM 88002 | 1                           | DRSEL-PL-ST<br>DRSEL-MA-MP<br>**DRSEL-MS-TI<br>DRSEL-PP-I-PI<br>DRSEL-PA   | 1<br>1<br>2<br>1<br>2       |
| Chief<br>OFC of Missile Electronic Warfare<br>Electronic Warfare Lab, ERADCOM<br>Fort Meade, MD 20755                           | 1                           | Cindas<br>Purdue Industrial Research Park<br>2595 Yeager Road<br>W. Lafayette, IN 47096                                | 1                           |
| Commander<br>US Army Electronics R&D Command<br>Fort Monmouth, NJ 07703   |                             | MIT - Lincoln Laboratory<br>Attn: Library (RM A-082)<br>PO Box 73<br>Lexington, MA 02173                               | 1                           |
| DELEW-D   | 1                           |  |                             |
| DELCS-D   | 3                           | NASA Scientific & Tech Info Facility   | 1                           |
| DELAS-D   | 1                           | Baltimore/Washington Intl Airport  |                             |
| DELS-D-AS   | 1                           | PO Box 8757, MD 21240  |                             |
| DELET-DD  | 2                           |  |                             |
| *DELET-BM (GWurthmann)  | 3                           | ITT Electron Tube Division   | 1                           |
| DELET-P   | 1                           | Box 100  |                             |
| DELS-D-L (Tech Lib)   | 1                           | Attn: Mr. R. Wertman   |                             |
| DELS-D-D  | 1                           | Easton, PA 18042   |                             |
| DELET-D   | 1                           |  |                             |
| Originating Office  | 25                          | Litton Industries<br>Electron Tube Division  | 1                           |
| Raytheon Company<br>Microwave & Power Tube Division<br>Foundry Avenue<br>Attn: Mr. D. Winsor<br>Waltham, MA 02154               | 1                           | 960 Industrial Road<br>Attn: Mr. R. Phillips<br>San Carlos, CA 94070   |                             |
| Watkins-Johnson<br>Electron Device Division<br>3333 Hillview Avenue<br>Attn: Dr. K. Niclos<br>Palo Alto, CA 94304               | 1                           | Varian Associates<br>Microwave Tube Division<br>611 Hansen Way<br>Attn: Dr. E. Lien<br>Palo Alto, CA 94303             | 1                           |
| Warnecke Electron Tubes, Inc.<br>175 W. Oakton Street<br>Attn: Dr. O. Doehler<br>Des Plains, IL 60018                           | 1                           | Hughes Aircraft Co.<br>Electron Dynamics Division<br>3100 W. Lomita Blvd.<br>Attn: Dr. J. Mendel<br>Torrance, CA 90509 | 1                           |