(12)

Report EECEN-WX016-B4



# EVALUATION OF HIGH POWER TUBES FOR LORAN-C USE

## Characteristics of the EIMAC Y-711 Power Grid Tube as used in the Second Intermediate Power Amplifier of the AN/FPN-44/45 Transmitter



Gary R. Sobotka
USCG Electronics
Engineering Center
Wildwood, N. J. 08260

11 November 1976

Interim Report for Period May 1975 - September 1976

~~This is an internal technical report to the Chief, Office of Engineering, USCG Headquarters, Washington, D. C.~~

COMMANDANT (G-EEE/63)
U. S. Coast Guard
Washington, D. C. 20590

Statement on front of report: This is an internal technical report should be deleted per Mr. Joseph Kowalski U.S. Coast Guard, G-EEE/63.

JEC
12/1/76

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| (14) 1. REPORT NUMBER: EECEN-WX016-B4 / 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| (6) 4. TITLE (and Subtitle): EVALUATION OF HIGH POWER TUBES FOR LORAN-C USE. | 5. TYPE OF REPORT & PERIOD COVERED: Interim Report for May 1975 - September 1976 |
| | 6. PERFORMING ORG. REPORT NUMBER |
| (10) 7. AUTHOR(s): Gary R. Sobotka | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: USCG Electronics Engineering Center, Wildwood, N. J. 08260 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: Commandant (G-EEE/63), U. S. Coast Guard, Washington, D. C. 20590 | (11) 12. REPORT DATE: 11 Nov[redacted]76 |
| | 13. NUMBER OF PAGES: 34 |
| (9) 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Interim rept. no. 1, May 75-Sep 76 | (12) 15. SECURITY CLASS. (of this report): 37p. |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; 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)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)


Problems in the operation of the EIMAC Y-711 Power Grid Tube when used in the second intermediate power amplifier of the AN/FPN-44/45 Transmitter have been encountered by LORSTAs DANA and EJDE. These problems involved numerous overloads and an inability to obtain rated transmitter output. Tests have been conducted to determine the nature, cause, and possible solution to these problems. The tests involved the operating


DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

410363

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20 (Continued)

parameters of the tube and transmitter such as tube dynamic characteristics, drive and pulse shape, biasing conditions, transmitter drive level, and tube high voltage breakdown level. The Y-711 tube exhibits a negative grid current region and will therefore overload the transmitter if overdriven. It is hypothesized that the problem encountered in the field is due to an imperfect drive waveform requiring higher drive levels than normal. Under correct conditions of pulse shape the tube works satisfactorily.

## ABSTRACT

Problems in the operation of the EIMAC Y-711 Power Grid Tube when used in the second intermediate power amplifier of the AN/FPN-44/45 Transmitter have been encountered by LORSTAs DANA and EJDE. These problems involved numerous overloads and an inability to obtain rated transmitter output. Tests have been conducted to determine the nature, cause, and possible solution to these problems. The tests involved the operating parameters of the tube and transmitter such as tube dynamic characteristics, drive and pulse shape, biasing conditions, transmitter drive level, and tube high voltage breakdown level. The Y-711 tube exhibits a negative grid current region and will therefore overload the transmitter if overdriven. It is hypothesized that the problem encountered in the field is due to an imperfect drive waveform requiring higher drive levels than normal. Under correct conditions of pulse shape the tube works satisfactorily.

## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF FIGURES
(Continued)

PROJECT WX016-B4

INTERIM REPORT NO. 1

EVALUATION OF H.P. TRANSMITTING
TUBES FOR LORAN-C USE

## 1.0 INTRODUCTION

### 1.1 BACKGROUND

The EIMAC Y-711 Power Grid Tube was developed as a replacement/second source for the ITT 8C25 Tube used in the second IPA of the AN/FPN-44 Transmitter. A set of three Y-711 tubes were received at EECEN on 4 August 1975. The tubes were operated at maximum transmitter drive into the antenna for continuous periods of 48 hours and 72 hours with no problems. The tubes were then sent to LORSTA DANA for further evaluation. An additional set of three Y-711 tubes were received on 4 September 1975. These tubes were also operated successfully and were shipped to LORSTA EJDE for further evaluation. The tubes sent to LORSTA EJDE operated satisfactorily; however, LORSTA DANA was unable to attain full output power with the Y-711 tubes installed. Both sets of tubes were returned to EECEN for use during the ITTAV development of AN/FPN-44A modifications. A second set of nine tubes were received at EECEN during February 1976. Of these tubes, four were sent to LORSTA EJDE and five were sent to LORSTA DANA. Both stations experienced overloads and an inability to attain full output power. The tubes at LORSTA DANA were returned to EECEN for further tests. This report summarizes the results of this testing.

## 2.0 SCOPE

### 2.1 PROJECT REQUIREMENTS

Commandant letter WX016-B4 of 7 May 1975 assigned Project WX016-B4 to evaluate high power transmitting tubes for Loran-C use. This phase of the project requires that the EIMAC Y-711 Tube's electrical and physical characteristics be thoroughly evaluated; that the problems encountered at LORSTAs DANA and EJDE be analyzed; and the causes and possible solutions of these problems be determined.

### 2.2 SCOPE OF THIS REPORT

This report presents data collected on seven of the EIMAC Y-711 Tubes. Of these tubes, two had been previously operated only at EECEN; three had been operated at LORSTA DANA; and two had not previously been operated in a transmitter. In addition these tubes were from three different production runs. The report includes data on normal and abnormal operating conditions for the second IPA and also briefly discusses the effect of drive shape on the Y-711 in the second IPA. In addition a brief discussion of the required value for the second IPA cathode resistance is included. The test data is presented in Section 3.0. Conclusions and recommendations are presented in Sections 4.0 and 5.0, respectively.

## 3.0 PROSECUTION OF REQUIREMENTS

The project was prosecuted in five basic steps: (1) The operation of the tubes in the EECEN AN/FPN-44 Transmitter to get a qualitative view of how well they worked; (2) An attempt to force overloads to determine the problem which occurred at LORSTAs DANA and EJDE; (3) A comparison of a sample of the tubes to determine their dynamic characteristics; (4) A high voltage test to determine if any of the tubes were shorted; and (5) An analysis of the effect of pulse shape on the achievable power output of the transmitter with the Y-711 tubes installed.

### 3.1 QUALITATIVE TUBE CHARACTERISTICS

The various Y-711 tubes originally at EECEN and those returned from LORSTA DANA were installed in the FPN-44 Transmitter and qualitatively tested to see if the same symptoms reported by LORSTA DANA would be reproduced. In each case the transmitter worked very well up to and beyond its rated output of 620 Amps into the antenna (the figure of 620 Amps as the rated peak antenna current is based on a peak PA plate swing of 15 kV and a peak PA plate current of 150 Amps driving into a 625 foot antenna). This test included two tubes which had never before been installed in a transmitter. As a result of this test it was determined that some difference between the EECEN and DANA transmitters must be responsible for differing operating characteristics. The following tests were devised in an attempt to isolate this difference.

### 3.2 FORCED OVERLOADS

An attempt was made to force overloads in order to determine the source of the overloads experienced at LORSTA DANA. This was done by two methods: (1) Varying the biasing conditions and (2) Increasing the drive beyond that normally required to drive the transmitter.

### 3.2.1 Effect of Biasing Conditions

Table 3-I shows the various biasing conditions on several of the tubes along with other pertinent data. The biases were adjusted over very wide ranges with resultant variations in output power. In each case despite wide variance from normal bias settings the transmitter was able to put out a minimum of 680 Amps without overloading. From this it is apparent that under any reasonable bias conditions the Y-711 tubes are able to supply enough drive to obtain more than the rated output of the transmitter.

### 3.2.2 Effect of Increased Drive Level

During the next testing phase the drive level was increased beyond that normally required to obtain full output from the transmitter in order to see if overloads could be generated. Increasing the drive beyond a certain level was observed to cause overloads when the Y-711 tubes were installed. This effect is explained in the following paragraphs.

#### 3.2.2.1 Qualitative Analysis of Grid Current in Power Grid Triode

Figures 3-1 and 3-2 are plots of the constant current characteristics of the 8C25N and Y-711 tubes. As can be seen by comparing these plots the Y-711 exhibits a negative grid current region while the 8C25N does not. This negative grid current region is a result of secondary emission from the grid. Referring to Figures 3-3 and 3-4 the grid characteristics of the Y-711 can be explained as follows. When the grid to cathode voltage is negative the electric field is such that no current flows to the grid (Figure 3-3a). When the grid to cathode voltage becomes slightly positive the electric field between the grid and cathode reverses so that now some electrons can be collected by the grid (Figure 3-3b). This results in a grid current flowing into the grid (positive current). As the grid voltage increases further another effect becomes apparent. This effect is secondary emission of electrons from the surface of the grid. This can be caused by two phenomena. The first is heating of the grid material. If the grid heats up to a high enough termperature the electrons within the material will obtain enough energy to overcome the work function of the material. This will result in an emission similar to cathode emission. The second effect is due to high energy electrons emitted from the cathode striking the grid with enough force to scatter grid electrons. The grid electrons which are thus scattered are available for current flow. If the grid voltage is low enough these scattered electrons do not have sufficient energy to escape the

**TABLE 3-I**
**REPRESENTATIVE SAMPLE OF BIAS SETTINGS USED DURING Y-711 EVALUATION**

| BIAS PARAMETER | | BIAS VALUES (BY TUBE SERIAL NO.) | | | | (RT 2nd IPA) (LT 2nd IPA) |
|---|---|---|---|---|---|---|
| | | GSL-495 GSL-497 | AGD-157 HSH-146 | AGD-157 HSH-146 | AGD-151 AGD-155 | AGD-157 AGD-146 |
| PA PLATE V | (kV) | 21.5 | 21.5 | 24.5 | 21.5 | 21.4 |
| IPA PLATE V | (kV) | 9.6 | 9.6 | 11 | 9.6 | 9.6 |
| IPA PLATE I | (A) | 0.25 | 0.18 | 0.2 | 0.10 | (0.08) |
| PA PLATE I | (A) | 2.2 | 1.6 | 1.9 | 1.5 | 2.05 |
| –5kV BIAS | (kV) | – 5.3 | – 5.2 | – 5.2 | – 5.3 | – 5.1 |
| LOW VOLTAGE | (V) | 600 | 600 | 600 | 600 | 600 |
| R 1st IPA CATH I | (μA) | 50 | 52 | 60 | 53 | 40 |
| L 1st IPA CATH I | (μA) | 50 | 52 | 60 | 53 | 48 |
| R 2nd IPA BIAS V | (kV) | 3.2 | 3.25 | 3.5 | 3.3 | 3.4 |
| L 2nd IPA BIAS V | (kV) | 3.2 | 3.25 | 3.5 | 3.25 | 3.4 |
| R 2nd IPA CATH I | (mA) | 330 | 250 | 300 | 275 | 95 |
| L 2nd IPA CATH I | (mA) | 300 | 245 | 300 | 200 | 95 |
| R PA BIAS I | (A) | 0.30 | 0.22 | 0.27 | 0.23 | 0.06 |
| L PA BIAS I | (A) | 0.38 | 0.23 | 0.33 | 0.26 | 0.07 |
| R PA GRID V | (kV) | 1.2 | 1.25 | 1.32 | 1.26 | 0.88 |
| L PA GRID V | (kV) | 1.2 | 1.25 | 1.26 | 1.27 | 0.82 |
| V1 CATH I | (A) | – | 0.35 | 0.48 | 0.35 | 0.95 |
| V2 CATH I | (A) | – | 0.45 | 0.46 | 0.40 | 0.80 |
| V3 CATH I | (A) | – | 0.35 | 0.49 | 0.35 | 0.80 |
| V4 CATH I | (A) | – | 0.45 | 0.46 | 0.40 | 0.80 |
| TP-6 | (A) | 740 | 800 | 810 | [illegible] | 880 |
| 2nd IPA PEAK CATH V | (V) | +1100 | +1200 | +1200 | +1100 | +1000 |
| 2nd IPA PEAK GRID V | (V) | – | +1500 | +1000 | – | +1000 |

FROM SETTINGS [illegible]

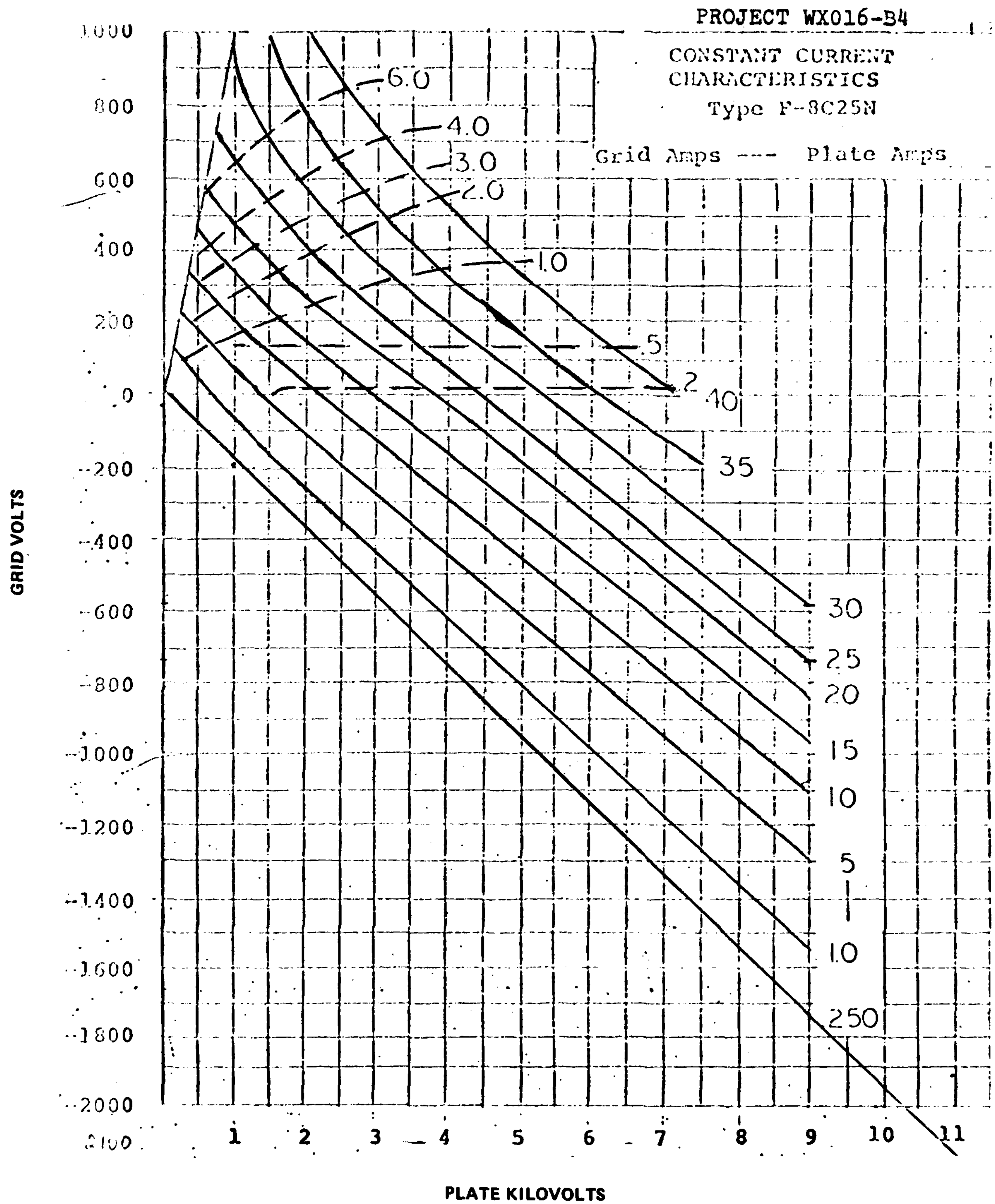



**Figure 3-1**

**Constant Current Characteristic For 8C25N**

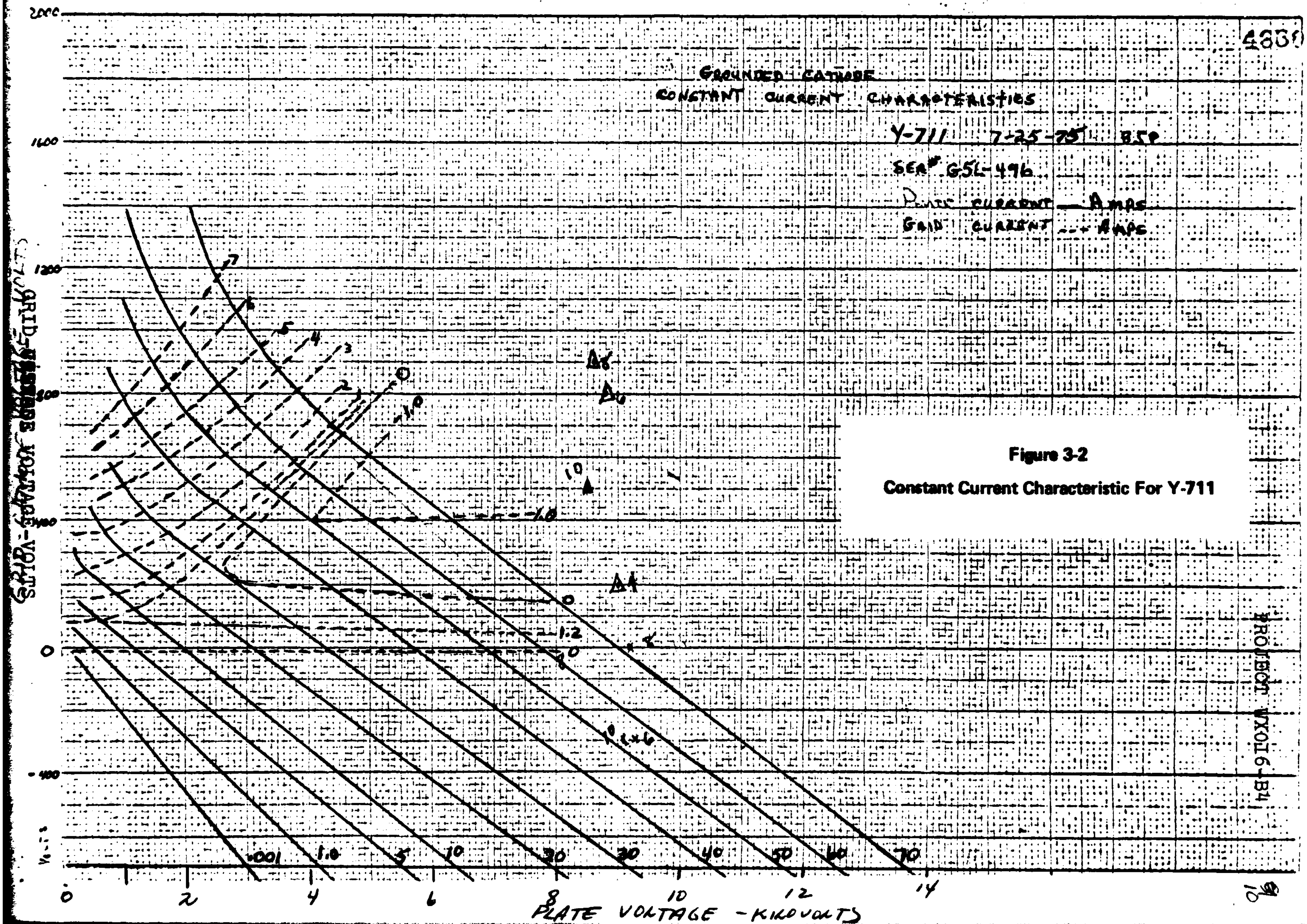



Figure 3-2

Constant Current Characteristic For Y-711

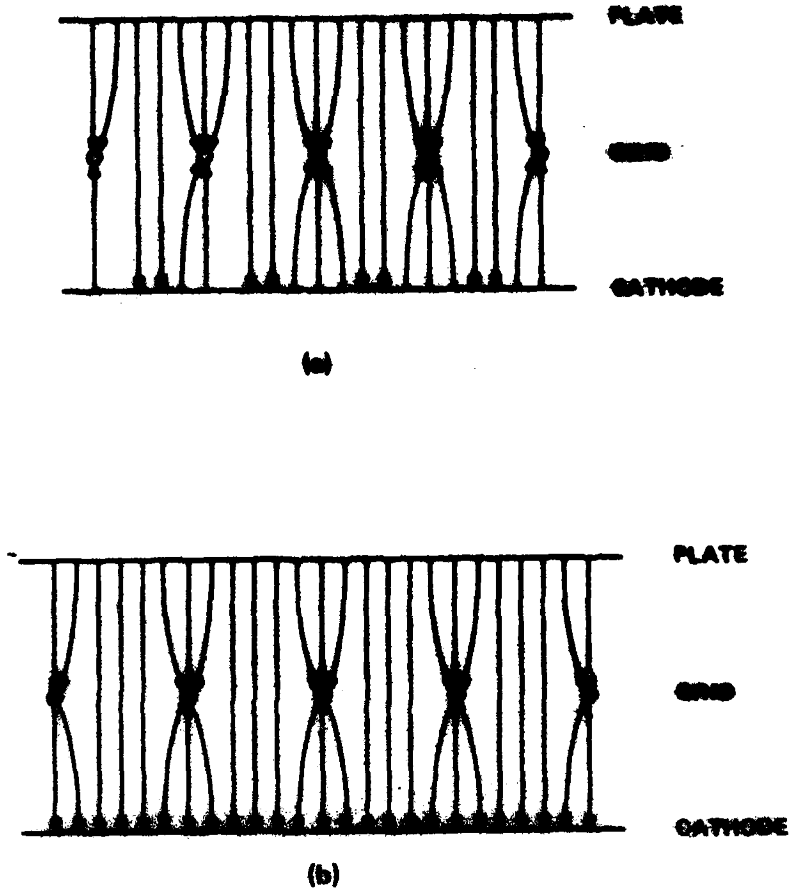



Figure [illegible]

Electric Field Internal To Space Grid Tube

(a) Grid To Cathode Volts < 0
(b) Grid To Cathode Volts > 0

PROJECT WX0116-B4

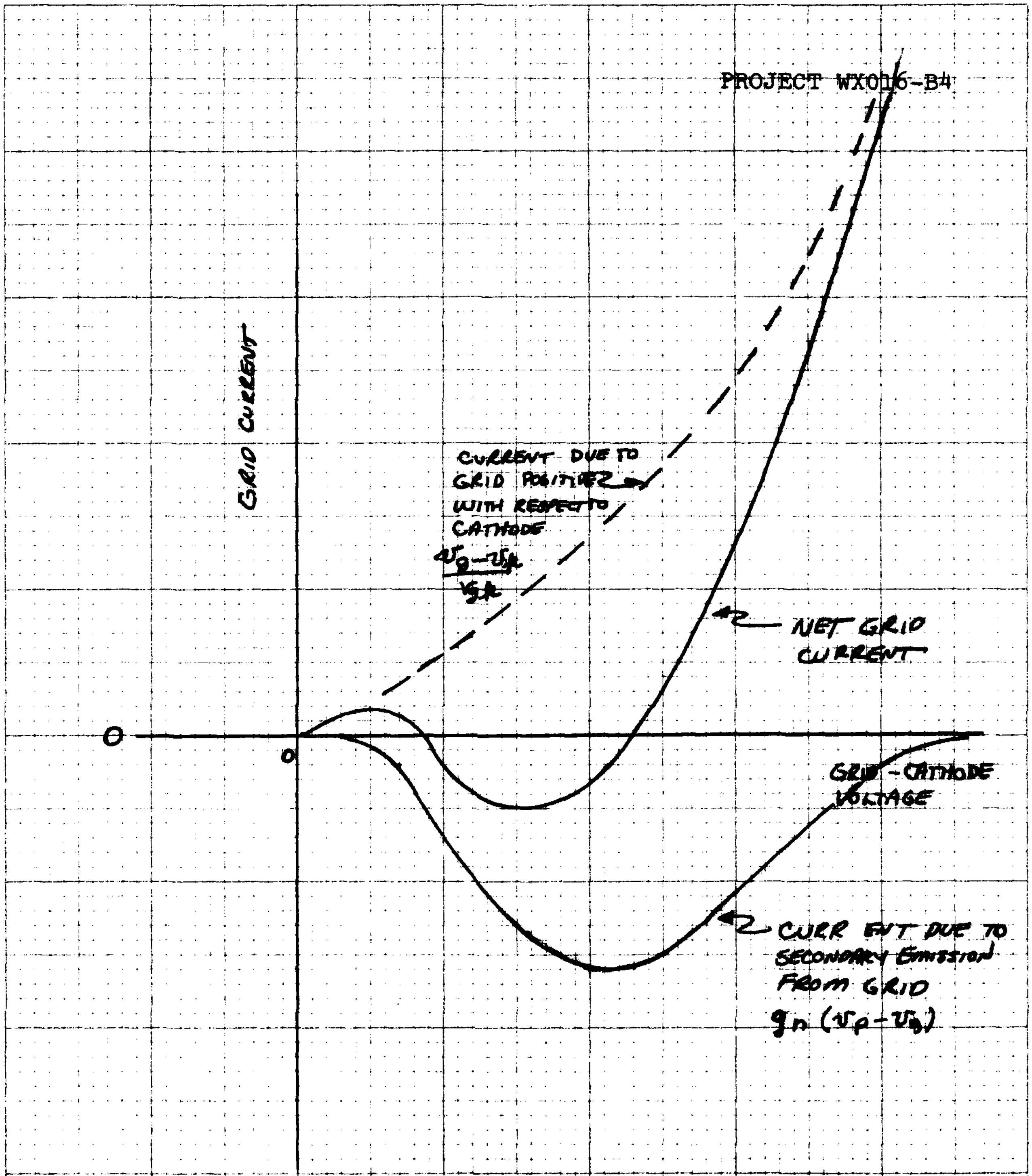


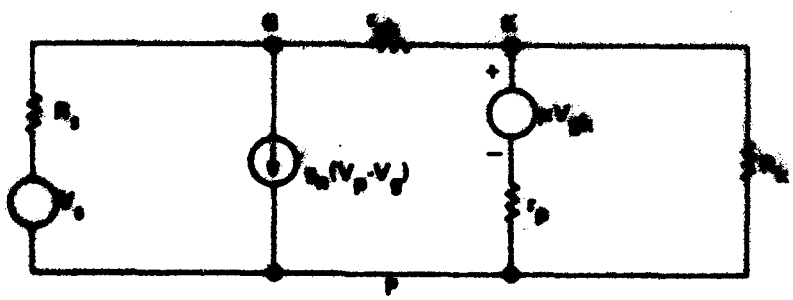

**Figure 3-4**

**Theoretical Curves For Grid Current In Tube With Negative Grid Current Region**

local grid field and hence fall back into the grid so that no net current is generated. As the grid voltage is increased the scattered electrons obtain more energy and are able, under the influence of the electric field to migrate to the plate. Under this condition a current flow from the plate to grid is generated (negative current). Note that this current and that generated from grid to cathode are in opposite directions. The current from plate to grid will increase to a peak and then decrease to almost zero as the grid voltage approaches the plate voltage. Combining the two types of grid current results in a net grid current as depicted in Figure 3-4. Additional information on these effects may be found in "Care and Feeding of Power Grid Tubes" a handbook prepared by the EIMAC Division of Varian.

3.2.2.2 Equivalent Circuit for Y-711 Tube in Cathode Follower Configuration

A small signal equivalent circuit for the Y-711 tube in the range including the negative grid current region with the tube connected as a cathode follower is shown in Figure 3-5.



[illegible]

Where:

- $V_s$ = Source Voltage
- $R_s$ = Source Resistance
- $g_h$ = Transconductance Due to Secondary Emission from the Grid
- $r_{gk}$ = Grid to Cathode Resistance Due to Grid - Cathode Voltage > 0
- $r_p$ = Plate Resistance
- $\mu$ = Voltage Gain
- $R_k$ = Second IPA Cathode Resistor

In this model $g_h$, $r_{gk}$ and $\mu$ are non-linear elements.

The current source $g_n$ ($V_p$ - $V_g$) generates positive feedback within the tube. As a result, if the grid voltage is increased above the level at which a negative grid current flows the stage will become unstable. This instability causes the stage to oscillate. This oscillation is coupled to the grids of the PA tubes causing them to overload. This effect is not present with the 8C25N Tube as this tube does not exhibit a negative grid current region, in any normal or abnormal region of operation. The positive grid current generated by the grid being positive with respect to the cathode creates a back voltage in the source resistance reducing the effect of increased grid voltage causing a self limiting action. As a result the drive on the grids of the 8C25N Tubes can be increased to its maximum without causing the problems found with the Y-711 Tubes.

This theory has been verified experimentally; with the Y-711 Tubes installed the transmitter will overload whenever the grid goes slightly positive with respect to the cathode. The result of this is that if the transmitter drive level is set to a point just below this critical point considerable overloads can be expected as transients, drive level variations, and other external effects increase the Y-711 grid voltage above this threshold. However, if the transmitter is correctly set up with the correct drive shape a sufficient buffer zone is present which will absorb these variations and operation will be stable. The Y-711 Tube has more than enough drive capability to drive the PA tubes to their theoretical limit at about -400 volts from the grid to the cathode. The key idea here is that the drive shape must be correct. The effects of incorrect drive shape are discussed in a later section. Although the problem noted in this section should never occur it is important to be aware of this basic limitation of the Y-711 Tube, as used in this application.

### 3.2.2.3 Effect of Second IPA Cathode Resistor on the PA Stage

The ITT 1086 Power Amplifier Tube exhibits a negative grid current region similar to that found in the Y-711. However since the PA stage is normally operated in the positive grid region, it was necessary to compensate for the instability this caused. This was accomplished by reducing the second IPA cathode resistor from 600 Ω to 300 Ω. The reason for this change can be understood by referring to Figure 3-6. Figure 3-6 is an equivalent circuit for the PA stage showing also the output of the preceding second IPA stage, where the variables $\mu$, $r_r$, $g_n$, $r_k$, $r_{gk}$ are the same as defined in Section 3.2.2, and $R_L$ is the PA load resistance. Notice that in this amplifier configuration the term $g_n$ ($V_p$ - $V_g$) does not appear directly across the input as in Figure 3-5.

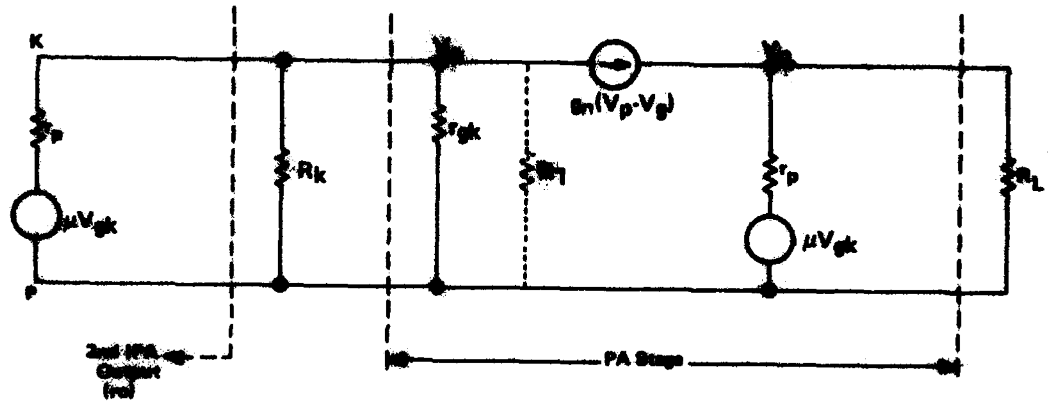



**Figure 3-6**
**Small Signal Equivalent**
**Circuit of PA Stage**

In order to obtain the equivalent input effect of this current source, MILLER'S theorem is applied to it as follows:

Writing the node equation at Vp gives:

$$V_p\left(\frac{1}{r_p}+\frac{1}{R_L}\right) - g_m(V_p - V_g) = \frac{\mu V_g}{r_p} \qquad (1)$$

Solving for [illegible] of $V_g$:

[illegible] (2)

Where: $g_m = \mu / r_p$

$g_p = 1 / r_p$

$g_L = 1 / R_L$

[illegible] Figure 3-7.

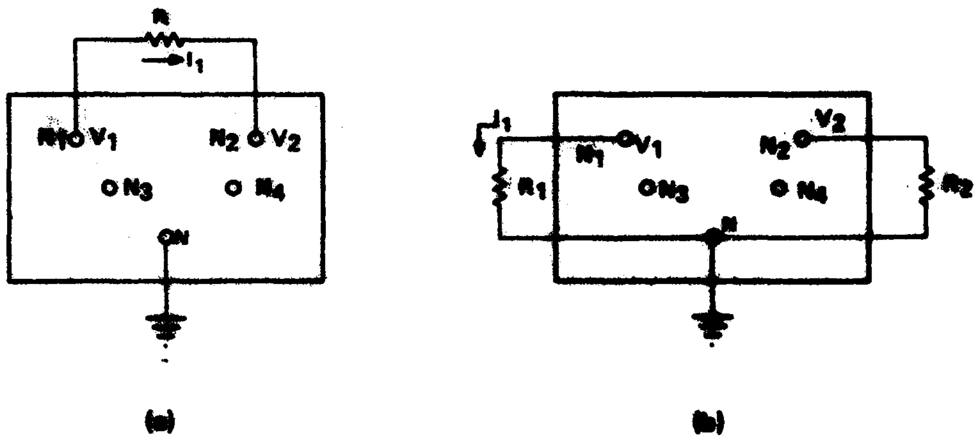



Figure 3-7
[illegible]

The current $I_1$ through R can be written:

$$I_1 = \frac{V_2 - V_1}{R} = \frac{V_1(k-1)}{R} = \frac{V_1}{R_1}$$

$$\therefore \quad R_1 = \frac{R}{k-1} \qquad (3)$$

Where: $k = {}^{V_2}/V_1$

Therefore if $R_1$ were shunted across the terminals $N_1 - N$, the current $I_1$ drawn from $N_1$ would be the same as that from the original circuit. A similar relation exists for $R_2$. Applying equation 2 to the term $g_n(V_p - V_g)$ in Figure 3-6 results in the following:

$$R_1 = \frac{{}^{1}/g_n}{\dfrac{g_m + g_n}{g_p + g_L - g_n} - 1}$$

$$R_1 = \frac{1}{g_n}\left(\frac{g_p + g_L - g_n}{g_m - g_p - g_L + 2g_n}\right) \qquad (4)$$

$R_1$ can be negative only if:

$$\frac{g_3}{g_4} < 0 \qquad (5)$$

Where $g_3 = g_p + g_L - g_n$

$g_4 = g_m - g_p - g_L + 2g_n$

From this two different conditions can apply:

$$g_3 > 0, \; g_4 < 0 \qquad (6)$$

$$g_3 < 0, \; g_4 > 0 \qquad (7)$$

Analysis of equations (6) and (7) lead to results showing that $R_1$ can have a negative region. Specifically from equations (5) and (6):

$$g_3 = g_p + g_L - g_n > 0 \qquad g_4 = g_m - g_p - g_L + 2g_n < 0$$

$$g_n < g_p + g_L \qquad g_n < \frac{g_p + g_L - g_m}{2}$$

But $g_m > 0$

$$\therefore \quad g_p + g_L > \frac{g_p + g_L - g_m}{2}$$

So $R_1 < 0$ for $g_n < \dfrac{g_p + g_L - g_m}{2}$ (8)

Likewise considering equations (5) and (7) leads to:

$R_1 < 0$ for $g_n > g_p + g_L$ (9)

From equations (8) and (9) it is clear that if $g_n$ is either very small or very large a negative input resistance could result. Referring to Figure 3-6 this negative resistance is in parallel with $R_k$, $r_{gk}$ and $r_o$ the output resistance of the second IPA. The total admittance $Y_{IN}$ is then:

$$Y_{IN} = \frac{1}{R_{IN}} = \frac{1}{r_o} + \frac{1}{R_k} + \frac{1}{r_{gk}} + \frac{1}{R_1} \qquad (10)$$

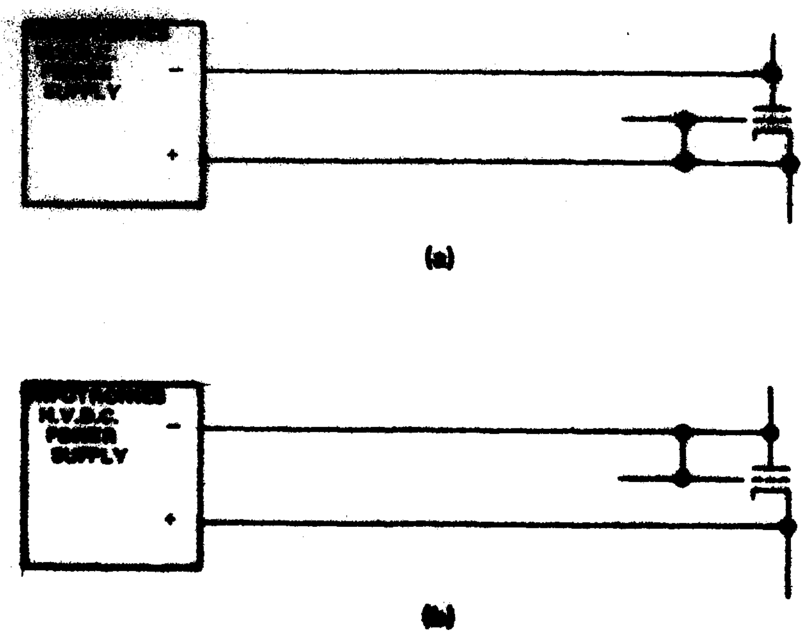
Since $R_1$, $r_{gk}$ and $r_o$ are fixed in the range of interest, only $R_k$ can be varied to swamp out $R_1$ making the net effect positive. By reducing $R_k$ from 600 Ω to 300 Ω this is accomplished. Reducing the value of $R_k$ increases the current through this resistor from approximately 4 to 8 Amps peak. However, this increase is relatively small compared with the total current supplied by the second IPA tube of about 40 Amps peak.

## 3.3 Y-711 DYNAMIC CHARACTERISTICS

In order to determine if all the Y-711s tested had the same characteristics dynamic transfer characteristics were obtained for six of the tubes. These characteristics were produced by driving the transmitter from the Pulse Generator (PGEN) of the AN/FPN-60 Transmitter Control Set with a square wave (PGEN setting, 99999900---0) and then varying the drive level. Taking readings of peak grid voltage and cathode voltage and current for a given half cycle produced the desired data. Figure 3-8 shows the transfer characteristics of the four tubes tested in the right second IPA location and Figure 3-9 shows the four tested in the left second IPA location. Two tubes were tested in both locations because the transmitter is not perfectly balanced and as a result the right side runs hotter than the left. Figures 3-10 and 3-11 show individual characteristics for the two tubes tested in both locations.

## 3.4 HIGH VOLTAGE TEST

Seven tubes were given high voltage (Hi-Pot) tests to determine if there were any internal shorts which might only show up under these conditions. The results are shown in Table 3-II. The test set up used is shown in Figure 3-12.




[illegible]

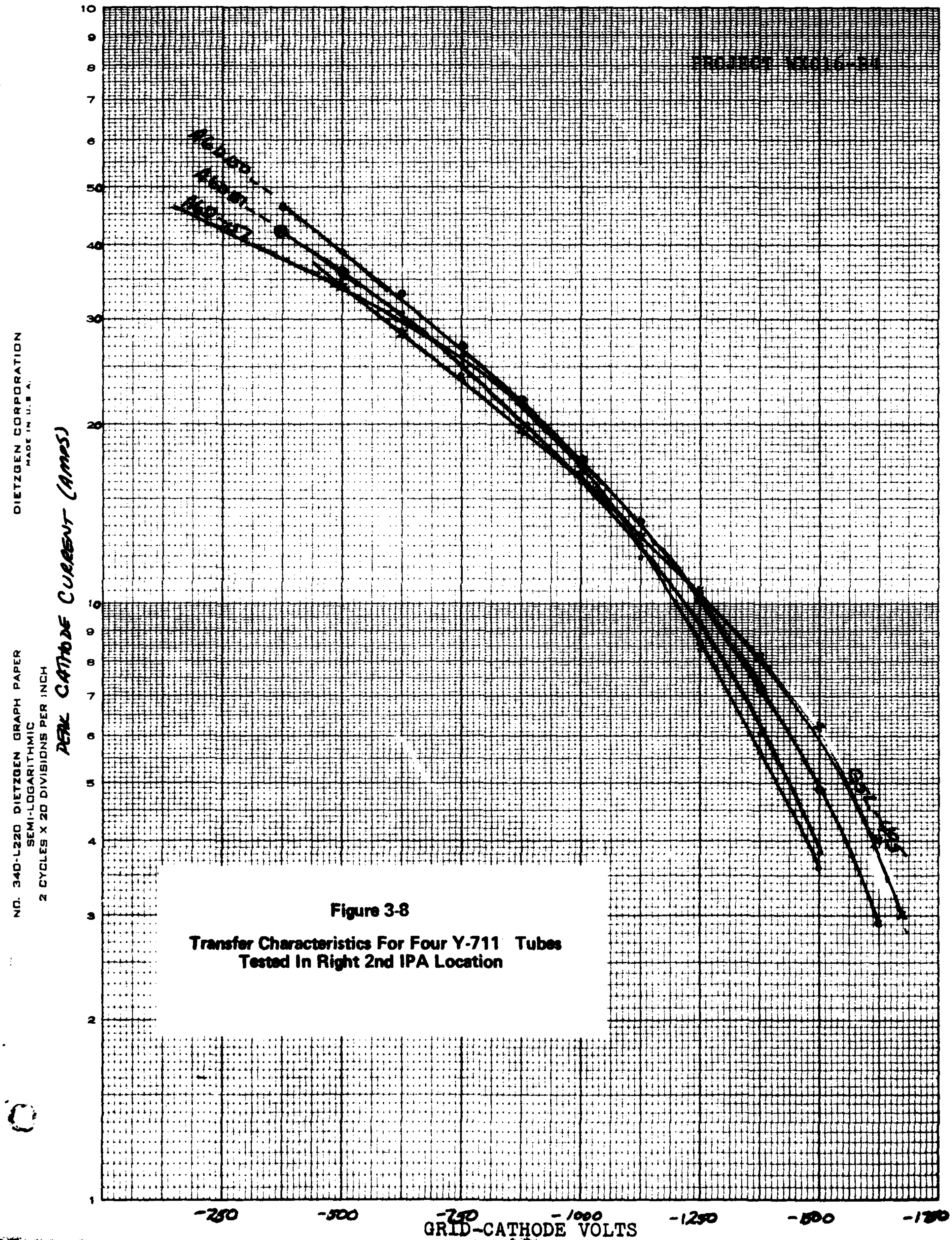



**Figure 3-8**

**Transfer Characteristics For Four Y-711 Tubes Tested In Right 2nd IPA Location**

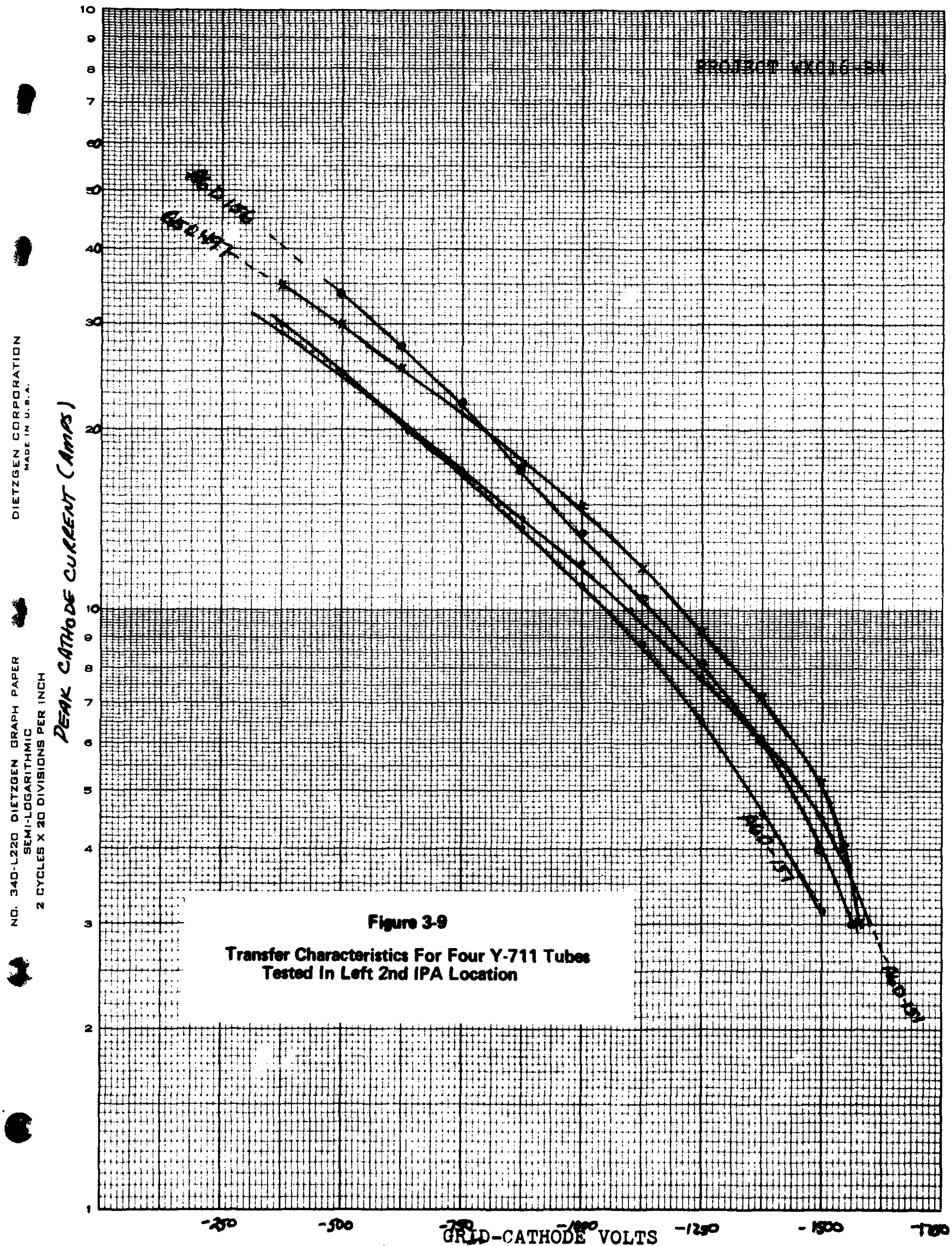



**Figure 3-9**

**Transfer Characteristics For Four Y-711 Tubes Tested In Left 2nd IPA Location**

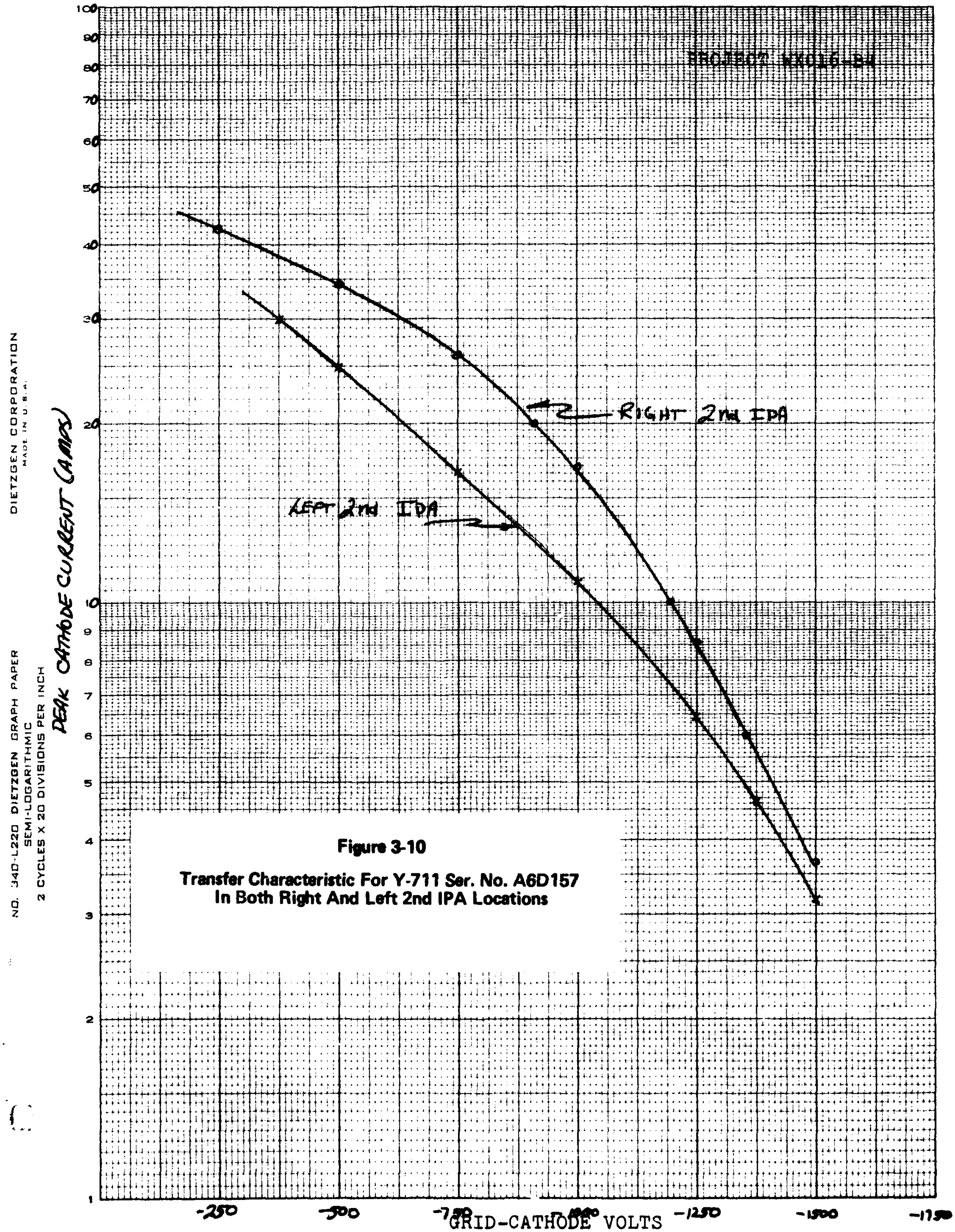



**Figure 3-10**

**Transfer Characteristic For Y-711 Ser. No. A6D157 In Both Right And Left 2nd IPA Locations**

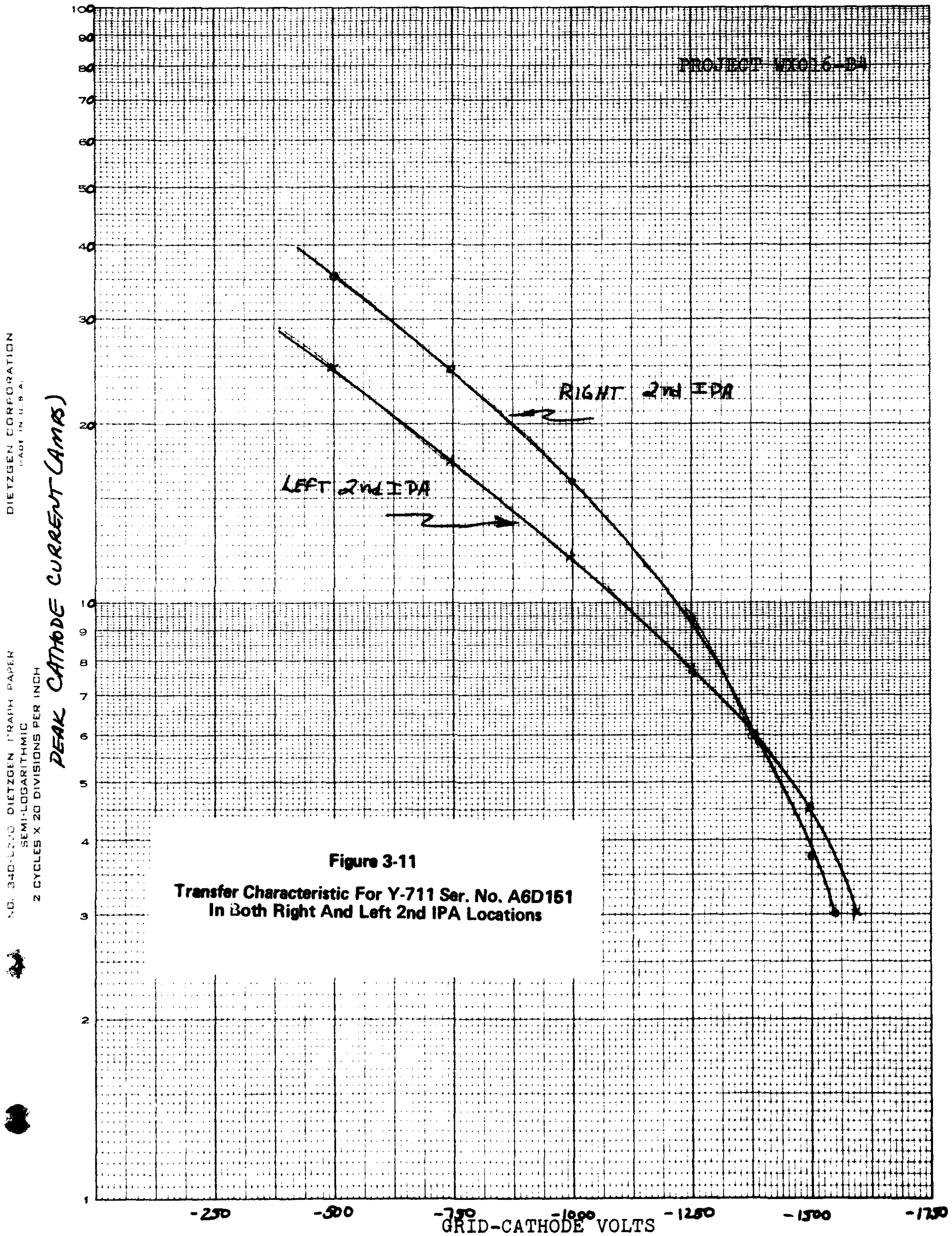



**Figure 3-11**

**Transfer Characteristic For Y-711 Ser. No. A6D151 In Both Right And Left 2nd IPA Locations**

## TABLE 3-II
## RESULTS OF HI-POT TEST

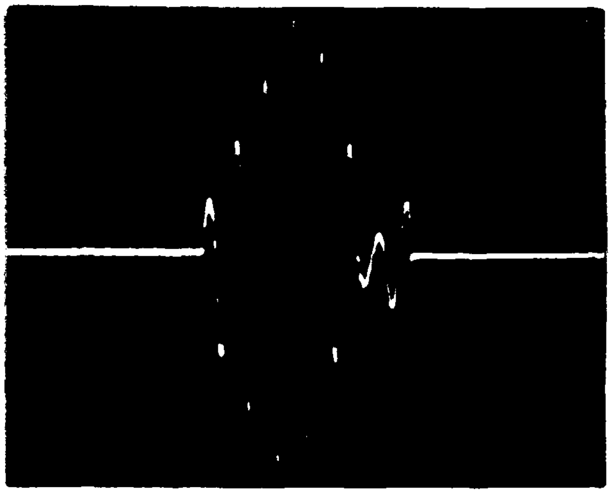
| TUBE SER NO. | TEST | VOLTAGE (kV) | CURRENT (μA) |
|---|---|---|---|
| HSH-146 | CATHODE | 10 | 10 |
| | PLATE | 20 | 140 |
| GSL-407 | CATHODE | 10 | 10 |
| | PLATE | 20 | 80 |
| GSL-405 | CATHODE | 10 | 10 |
| | PLATE | 20 | 120 |
| ASD-150 | CATHODE | 10 | 9.8 |
| | PLATE | 18.5 | 300 |
| ASD-156 | CATHODE | 10 | 1 |
| | PLATE | 20 | 22 |
| ASD-157 | CATHODE | 10 | 60 |
| | PLATE | 19.5 | 275 |
| ASD-161 | CATHODE | 10 | 9.5 |
| | PLATE | 20 | 16 |

On the cathode to grid test the voltage was slowly increased to 10 kV and the current noted. Similarly on the plate to grid test the voltage was slowly increased to approximately 20 kV and the current noted. This test shows that while the tubes are not identical in their high voltage characteristics none of them are shorted.

### 3.5 EFFECT OF DRIVE SHAPE

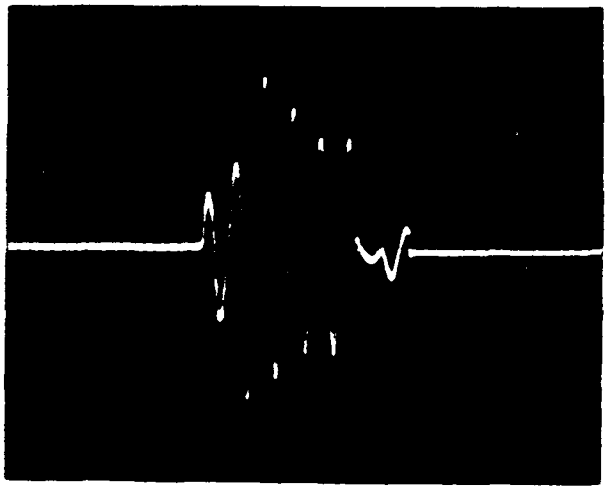
The final test involved determining the effect of drive shape on the operation of the Y-711 Tube. In this test a variety of drive waveforms were generated and used to drive the transmitter. The drive shapes used included the two drives used at LORSTA DANA, (based on DANA PGEN settings), a drive built at EECEN and the ITT network drive as shown in Figure 3-13. With each drive shape the drive level was increased until either the voltage at the cathodes of both second IPAs was at least +1200 V or until just before the transmitter overloaded, as was the case with the DANA drives. At this point pictures were taken of the right and left second IPA grid and cathode voltages and of the output pulse at TP-5. These pictures are included as Figures 3-14 through 3-16. The pictures for the two DANA drive shapes were taken without feedback while those for the EECEN drive were taken with feedback (pictures for ITT drive not available). The reason for this difference is that the drives in each case were designed to operate in that particular mode. Data for the other mode in each case is shown in Table 3-III along with a summary of data from Figures 3-13 to 3-17.

The results of this test are quite dramatic. The drive using the LORSTA DANA PGEN settings results in at least 100 Amps less peak antenna current for similar peak second IPA cathode voltages as the EECEN and ITT drives as can be seen in Figure 3-17 and Table 3-III. This can be explained by referring to Figures 3-13 through 3-16. The highly peaked drive generated by the DANA PGEN settings (Figure 3-13a, b) as compared with the EECEN (Figure 3-13c) and ITT drives (Figure 3-13d), causes the low output power. In order to get a specific average energy in an output pulse it is necessary to have a drive with a proportional average energy. This average energy is not attainable with the DANA drives because the very high peaks drive the Y-711 Tubes into an unstable condition before it can be reached. For the DANA drive Figures 3-14 and 3-15 show that the left second IPA grid and cathode voltages are almost equal at their peak. However, as shown in Figure 3-16 and Table 3-III the EECEN and ITT drives have a minimum of -300 V differential between the grid and cathode of the second IPA stage. With the DANA drive



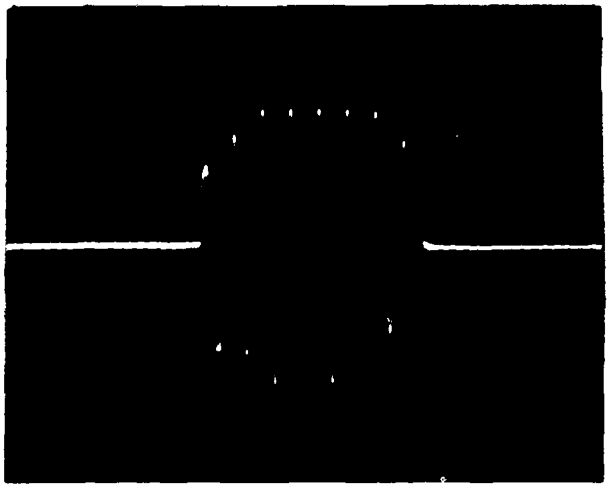
(a). DANA DRIVE WAVEFORM
PGEN No. 1 (24687412)

Scale:
Vertical: Uncalibrated
Horizontal: 20 μs/Div.



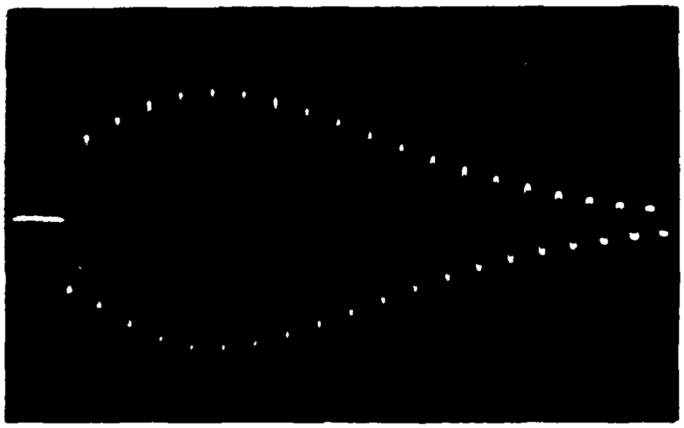
(b). DANA DRIVE WAVEFORM
PGEN No. 2 (23654401)

Scale:
Vertical: Uncalibrated
Horizontal: 20 μs/Div.



(c). EECEN DRIVE WAVEFORM
(3444555555545344)

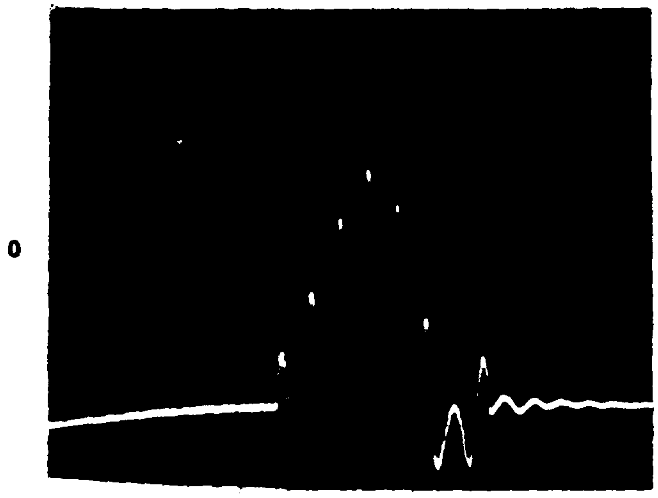
Scale:
Vertical: Uncalibrated
Horizontal: 20 μs/Div.



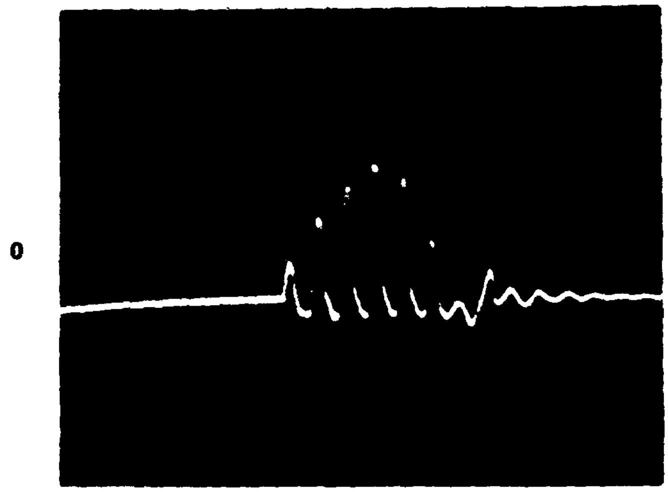
(d). ITT NETWORK DRIVE

**Figure 3-13: DRIVE WAVEFORMS**

**(a), (b) and (c) to same vertical scale. (d) for reference only.**

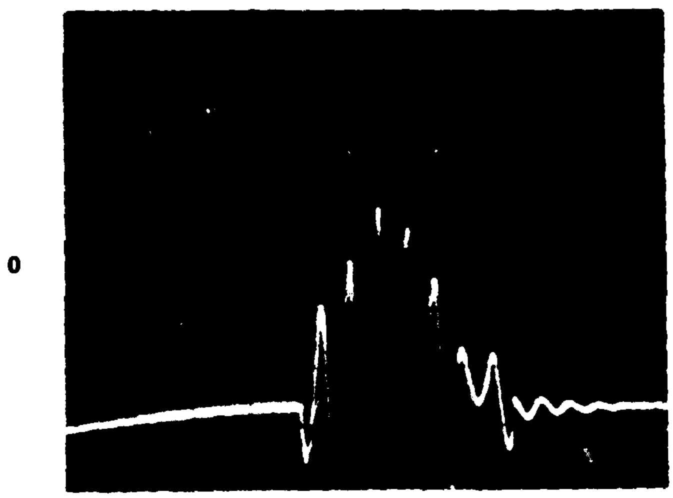



(a). LEFT GRID VOLTAGE

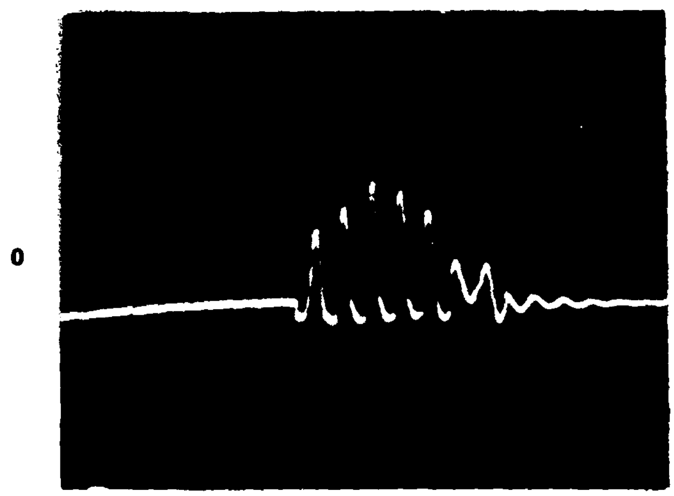



(b). LEFT CATHODE VOLTAGE

Scale:
Vertical: 1000 V/Div.
Horizontal: 20 μs/Div.




(c). RIGHT GRID VOLTAGE

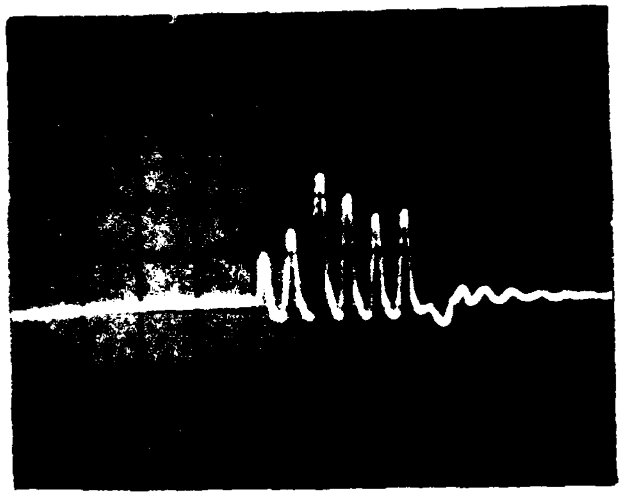



(d). RIGHT CATHODE VOLTAGE

Figure 3-14

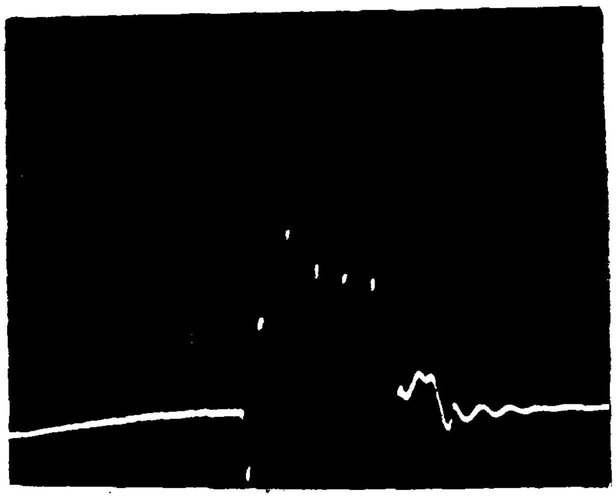
2nd IPA WAVEFORMS WITH DANA PGEN
NO. 1 DRIVE (Without Feedback)


(a). LEFT GRID VOLTAGE

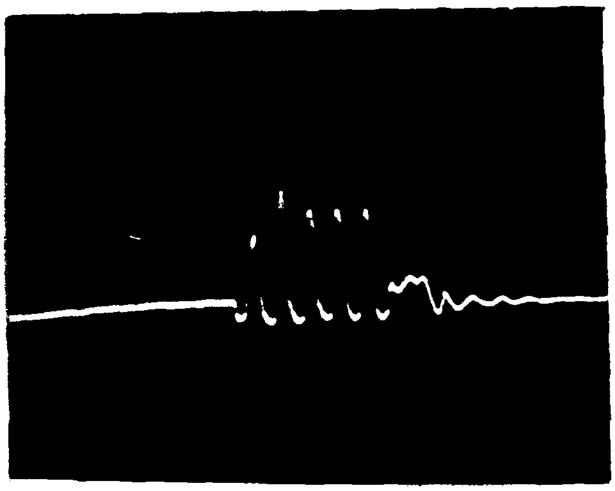



(b). LEFT CATHODE VOLTAGE

**Scale:**
Vertical: 1000 V/Div.
Horizontal. 20 $\mu$s/Div.



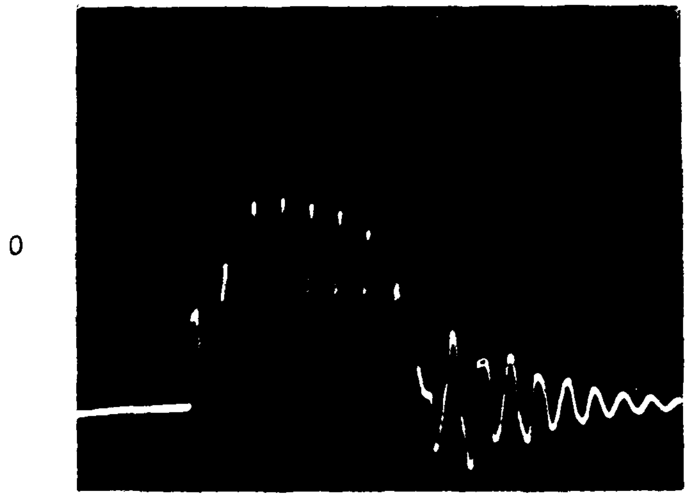

(c). RIGHT GRID VOLTAGE



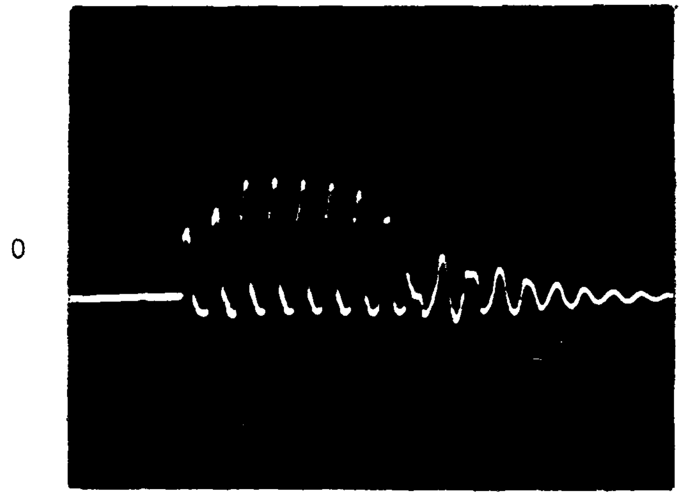

(d). RIGHT CATHODE VOLTAGE

**Figure 3-15**

**2nd IPA WAVEFORMS WITH DANA PGEN NO. 2 DRIVE**
**(Without Feedback)**

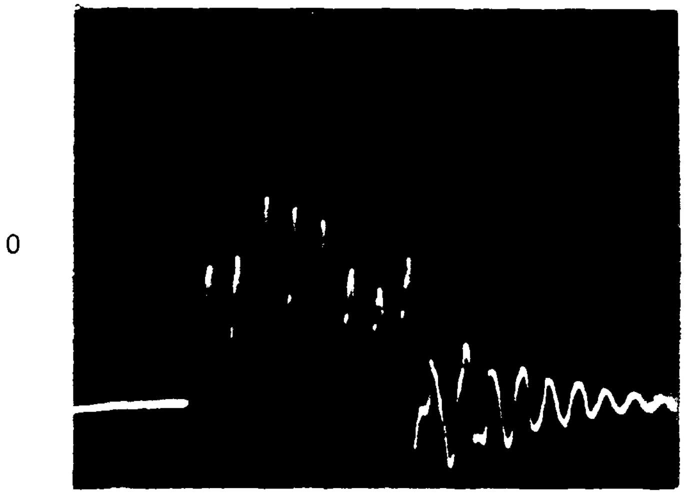



(a). LEFT GRID VOLTAGE

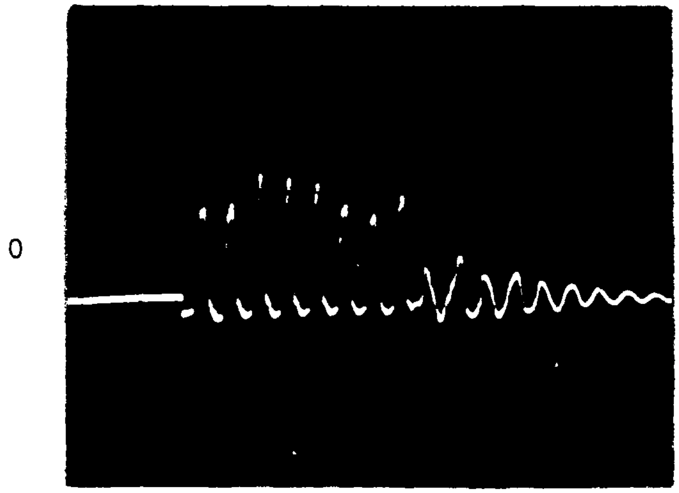



(b). LEFT CATHODE VOLTAGE

Scale:
Vertical: 1000 V/Div.
Horizontal: 20 μs/Div.



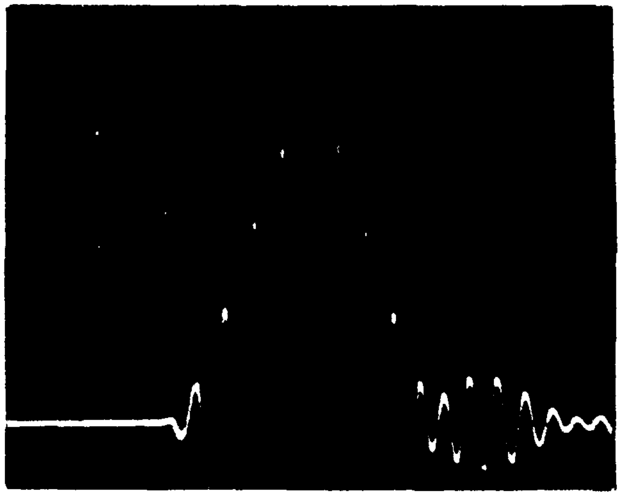

(c). RIGHT GRID VOLTAGE




(d). RIGHT CATHODE VOLTAGE

**Figure 3-16**

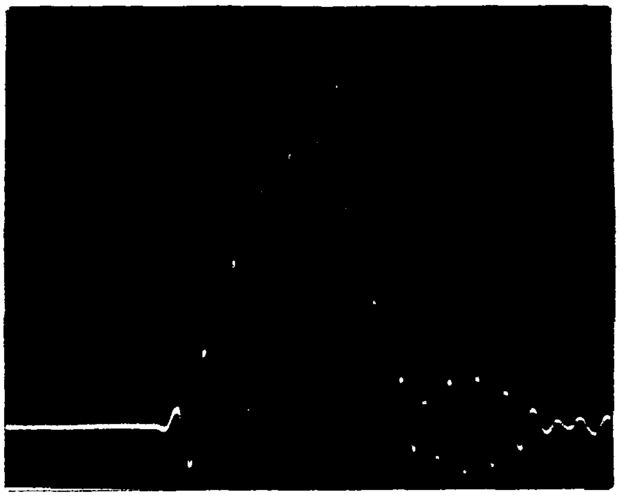
**2nd IPA WAVEFORMS WITH EECEN DRIVE**
**(With Feedback)**



(a). OUTPUT PULSE FOR DANA PGEN No. 1 DRIVE

Scale:
Vertical: 10 V/Div.
Horizontal: 20 $\mu$s/Div.

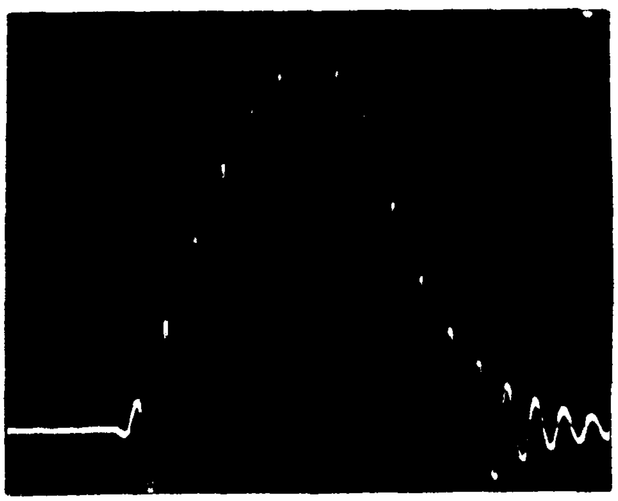
Pulse Amplitude At Peak = 55 V Without Feedback



(b). OUTPUT PULSE FOR DANA PGEN No. 2 DRIVE

Scale:
Vertical: 10 V/Div.
Horizontal: 20 $\mu$s/Div.

Pulse Amplitude At Peak = 50 V Without Feedback



(c). OUTPUT PULSE FOR EECEN DRIVE

Scale:
Vertical: 10 V/Div.
Horizontal: 20 $\mu$s/Div.

Pulse Amplitude At Peak = 64 V With Feedback

**Figure 3-17**

**OUTPUT WAVEFORMS AT TP-5 FOR VARIOUS DRIVES**

## TABLE 3-III

### ANTENNA CURRENT FOR VARIOUS DRIVES – WITH SIMILAR CONDITIONS AT THE CATHODE OF THE SECOND IPA

| DRIVE | RIGHT GRID VOLTS | RIGHT CATHODE VOLTS | LEFT GRID VOLTS | LEFT CATHODE VOLTS | ANTENNA CURRENT (AMPS) |
|---|---|---|---|---|---|
| ITT | | | | | |
| W/FEEDBACK | +600 | +1200 | + 900 | +1400 | 600 |
| W/O FEEDBACK | +600 | +1200 | + 800 | +1400 | 650 |
| PGEN (SECEN) [illegible] | | | | | |
| W/FEEDBACK | +400 | +1200 | + 300 | +1200 | 640 |
| W/O FEEDBACK | +400 | +1200 | + 500 | +1300 | 600 |
| PGEN (DANA) No. 1 224466 [illegible] 77441122 | | | | | |
| W/ FEEDBACK | +850 | +1050 | +1300 | +1400 | 400 |
| W/O FEEDBACK | +900 | +1200 | +1600 | +1500 | 550 |
| PGEN (DANA) No. 2 22 [illegible] 11 | | | | | |
| W/FEEDBACK | +100 | + 800 | +1300 | +1300 | 450 |
| W/O FEEDBACK | +[illegible] | +1100 | +1200 | +1300 | 500 |

operating at the levels indicated in Figures 3-14 and 3-15 multiple overloads would be expected and in fact during the above testing many overloads were experienced.

The problems experienced at LORSTA DANA are hypothesized to result from this combination of drive shape and the Y-711 Tube. A good pulse is attainable when using the 8C25 Tube because of the self-limiting action described in Section 3.2.2.2. Apparently the drive level is increased until the drive is compressed into something closely resembling the EECEN drive by the action of the 8C25 Tubes. An additional unknown factor is that DANA has an approximately 600-feet long transmission line between the transmitter and antenna. The result of this line could be that a different drive is required. However, since the same effect observed at DANA occurred also at EECEN it is believed that the net effect of the line is minimal. It is believed that by readjusting their drive shape the Y-711 Tubes can be operated satisfactorily at LORSTA DANA.

## 4.0 CONCLUSIONS

4.1 The EIMAC Y-711 Tube works very well as the second IPA in the FPN-44 Transmitter provided that the drive is correctly set up.

4.2 It is possible to drive the Y-711 into an unstable condition which will cause a transmitter overload. This is an inherent limitation of the tube which should never be reached in normal operation. When used in conjunction with the Y-711 it is also possible to cause an unstable condition in the 1086 power amplifier tubes. This instability can be eliminated by changing the cathode resistor of the second IPA from 600 to 300 Ω.

4.3 All the tubes tested have similar transfer characteristics so that interchanging or replacing tubes should have minimal effect on transmitter operation requiring only rebiasing and adjustment of overall drive level.

4.4 All the tubes passed a Hi-Pot test.

4.5 Drive shape appears to have a dramatic effect on the ultimate power output when using the Y-711 Tube. It is much more critical to have the correct drive than with the 8C25 Tube due to the instability in the Y-711.

## 5.0 RECOMMENDATIONS

5.1 This phase of Project WX016 was assigned to investigate problems which occurred primarily at LORSTA DANA but also at LORSTA EJDE. The results of the tests indicate areas which might have been the cause of the problems experienced at DANA. However, because of certain differences between the DANA installation and that at EECEN (primarily the transmission line) it is unknown if our results will in fact solve DANA's problems. Therefore, it is recommended that a set of Y-711 Tubes be sent to LORSTA DANA for further testing, that EECEN personnel travel to DANA to conduct these tests, and that approximately 8 hours of off-air time be authorized to allow on-air testing. The proposed tests will be a reduced version of the tests conducted at EECEN. These tests will consist of Time Waveform Analysis of grid voltage, cathode voltage and cathode current of the second IPA, under the following conditions:

a. present tube complement, PGEN settings and drive level;

b. Y-711 installation, present PGEN settings and various drive levels; and

c. Y-711 installation, modified PGEN settings and various drive levels.

These tests will determine the validity of the EECEN premise that the Y-711 is less tolerant of PGEN settings which result in second IPA grid voltages which are in the positive grid-cathode voltage region. In addition it is anticipated that new PGEN settings and adjustment procedures will be developed which allow Y-711 replacement to be used at LORSTA DANA and other FPN-44/45 installations.

5.2 It is recommended that a Field Change to the AN/FPN-44 Transmitter and its associated technical manual be promulgated which changes the value of the second IPA cathode resistor from 600 Ω to 300 Ω in all AN/FPN-44 Transmitters. This Field Change should specify that the 8C25N and Y-711 Tubes be used interchangeably (in sets only) only when this modification is completed. It should be emphasized that the 8C25N and Y-711 have different specifications and characteristics and hence should never be mixed in the same transmitter.

5.3 It is also recommended that a more precise procedure for building a Loran-C pulse than the reference envelope method be developed and promulgated as a Type 4 Field Change to the AN/FPN-60 TCS Manual. This change should emphasize that when the Y-711 tube is used extreme care must be taken to insure that correct drive shape and drive level is used. This drive shape should be as "flat" as possible consistent with obtaining a good output pulse. Highly peaked drive shapes such as those shown in Figure 3-13(a), (b) must be avoided. The recommended procedure whould be to build the Loran-C pulse at relatively low output power (~ 2/3 of peak) and low drive level (to avoid saturating any transmitter stage) then by using an oscilloscope with an input from RF OPERATE, build the pulse half cycle by half cycle using the pulse generator thumbwheel switches and observing the amplitudes on the oscilloscope (this must be done with the PGEN in half cycle mode). Finally increase the drive level to the desired level and fine-tune the pulse shape. This procedure is obviously incomplete and is included here only for reference.

This procedure will be used to build a new pulse at LORSTA DANA using a calculator to determine half-cycle, and total error if recommendation 5.1 is approved.

## 6.0 PROJECT STATUS

The testing phase of this project at EECEN is complete. Additional testing must be done in the field. The Project Manager is LT G. R. SOBOTKA.