NASA CONTRACTOR REPORT

NASA CR-526

EFFECTS OF ELECTRON RADIATION ON UNIJUNCTION TRANSISTORS

by H. L. Flescher and E. A. Szymkowiak

Prepared by
MARTIN-MARIETTA CORPORATION
Baltimore, Md.
for Goddard Space Flight Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JULY 1966

NASA CR-526

EFFECTS OF ELECTRON RADIATION ON UNIJUNCTION TRANSISTORS

By H. L. Flescher and E. A. Szymkowiak

Prepared under Contract No. NAS 5-3734 by
MARTIN-MARIETTA CORPORATION
Baltimore, Md.
Martin Co., Baltimore per mlm 12 Aug 66
for Goddard Space Flight Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $3.00

FOREWORD

This test report was prepared by the Martin Company, a Division of Martin Marietta Corporation, Baltimore, Maryland, on National Aeronautics and Space Administration Contract NAS5-3734, Work Order No. 716-W89495. The work was administered under the technical direction of Frederick Gordon, Radiation Effects Group, NASA-Goddard, Greenbelt, Maryland. The work was performed by personnel from the Radiation Physics Section of Martin-Baltimore over the period 21 February - 29 April 1966. The measured data are recorded in Martin Engineering Laboratories Notebook No. 7145.

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONT.)

LIST OF TABLES

EFFECTS OF ELECTRON RADIATION

ON UNIJUNCTION TRANSISTORS

I. INTRODUCTION

A report is given which covers a ten week effort to measure the effects of 1.5 Mev electron radiation on the terminal characteristics of selected unijunction transistors. The devices selected which reflect NASA-Goddard interests are identified in Table 1. The electron irradiations were conducted at the

Table 1a. Unijunction Transistors Tested

Type No.	Manufacturer	No. of Samples
2N1671B	Texas Instrument	12
2N3980	Texas Instrument	12
2N3484	Motorola	12

Goddard 1.5 Mev Van de Graaff Accelerator Facility. Measurements were made before and after irradiation and selected in-situ measurements were made after exposure to electron fluence levels in the range 10^{12} to 10^{16} electrons/cm^2.

The twelve samples of each unijunction transistor type were divided into four groups of three parts each: group no. 1 was for control, group no. 2 was irradiated at zero bias, group no. 3 was irradiated at one bias level, and group no. 4 was irradiated at a second bias level. The pre-and post-irradiation measurements on each part type included:

R_{BB}	Interbase Resistance
V_V	Valley Voltage
V_P	Peak Point Voltage
I_{B_2} (mod)	Interbase Modulated Current
V_E (sat)	Emitter Saturation Voltage
η	Intrinsic Stand-off Ratio
I_{eo}	Emitter Reverse Current
I_p	Peak Point Emitter Current

The in-situ measurements included R_{BB}, V_V, V_p, η, and $V_{E\ (sat)}$.

The following sections of this report present a description of the devices tested, test methods, a tabulation of measured data, a presentation of selected data in graphical form, and a summary of the significant results of the measurements program.

II. SUMMARY

This section summarizes the ten week experimental program to measure the effects of 1.5 Mev electron radiation on selected unijunction transistors. Three types of unijunction transistors (12 of each type) were tested (2N1671B, 2N3980, 2N3484) covering grown, planar, and annular construction, respectively. Three devices of each type were irradiated at bias levels (Base 2 - Base 1, emitter open) of 0 volts, 12 volts, and 20 volts. The additional three devices of each type were used as controls. The irradiated devices were exposed to electron fluence levels of 10^{12}, 10^{13}, 10^{14}, 10^{15}, 3×10^{15}, 5×10^{15}, 7×10^{15}, and 10^{16} e/cm^2 (E = 1.5 Mev) as mutually agreed by F. Gordon (NASA-Goddard) and H. Flescher (Martin).

The unijunction device parameters monitored before and after irradiation include: (1) interbase resistance (R_{BB}); (2) valley voltage (V_V); (3) peak point voltage (V_p); (4) emitter saturation voltage ($V_{E\ (sat)}$); (5) intrinsic standoff ratio (η); (6) interbase modulated current ($I_{B2\ (mod)}$); (7) emitter reverse current (I_{eo}); and (8) peak point emitter current (I_p). The in-situ measurements included parameters 1 through 5 above as a function of bias level during exposure and electron fluence. It was originally intended that I_{B2} (mod) be measured in-situ but the recorded data did not yield information on this parameter as originally planned. All terminal characteristics were measured at a bias level of 10 volts to provide a common comparison for the experimental data.

The measured data are tabulated in Section V and presented graphically in Section VI of this test report. Table 1b presents a summary of the general observations made on each part parameter. In general, this table suggests that significant changes, with some bias dependence, occur in the parameters measured at levels which range from about 5×10^{14} to 1×10^{15} e/cm^2 (E = 1.5 Mev) for the devices tested. As stated in the table this judgment is made without regard to part application. Catastrophic failure, on the other hand, is a stronger function of bias as evidenced by the summary information in Table 1c. Here catastrophic failure is identified by the disappearance of the valley voltage (V_V), the part no longer performing as a unijunction device. Also from Table 1c the data suggest that the grown junction constructed device (2N1671B) is susceptible to catastrophic failure at an electron fluence level lower than that for the annular planar (2N3484) and the diffused planar (2N3980) constructed devices.

From the data presented in this report it is expected that the three device types tested could probably be used satisfactorily at electron fluence levels ranging to about 5×10^{14} e/cm^2. For applications where small changes in selected unijunction parameters are critical or where electron exposure levels greater than 5×10^{14} e/cm^2 are expected, then additional testing is suggested. The purpose of such testing would be to identify more quantitatively the bias dependence and magnitude of response of unijunction terminal properties using a sample size larger than three for reasons of better statistics.

Table 1b. Summary of Measured Results

Part	Figure No.	Parameter	Apparent Bias Dependence	Approximate Fluence Level Where Change in Significant
2N3484	23	η	None observed	$0.3 - 1 \times 10^{15}$
	22	V_E (sat)	None observed	$0.3 - 1 \times 10^{15}$
	21	V_p	None observed	$0.3 - 1 \times 10^{15}$
	20	V_v	degradation is delayed in biased units	$0.1 - 1 \times 10^{15}$
	19	R_{BB}	Some	$0.3 - 1 \times 10^{15}$
	(Table 19)	I_{B2} (mod)$^{(b)}$	None observed	—
	(Table 18)	I_{eo}(b)	less damage at higher bias levels	—
	(Table 18)	$I_p^{(b)}$	None observed	—
2N3980	18	η	Less degradation for biased units	See Fig. 19
	17	V_E (sat)	None observed	$1 - 3 \times 10^{15}$
	16	V_p	Less degradation for biased units	$0.1 - 3 \times 10^{15}$
	15	V_v	None observed	$0.5 - 1 \times 10^{15}$
	14	R_{BB}	Some	$1 - 5 \times 10^{15}$
	(Table 19)	I_{B2} (mod)$^{(b)}$	None observed	—
	(Table 17)	$I_{eo}^{(b)}$	None observed	—
	(Table 17)	$I_p^{(b)}$	None observed	—
2N1671B	13	η	Some	$0.3 - 5 \times 10^{15}$
	12	V_E (sat)	Some	$0.1 - 3 \times 10^{15}$
	11	V_p	Less change for zero biased units	$0.5 - 1 \times 10^{15}$
	10	V_v	Degradation is delayed in biased units	$0.02 - 0.2 \times 10^{15}$

(Cont.)

Table 1b.

Part	Figure No.	Parameter	Apparent Bias Dependence	Approximate Fluence Level Where Change in Significant
	9	R_{BB}	None to 3 x 10^{14}	0.3 - 1 x 10^{15}
	(Table 19)	$I_{B2\ (mod)}$ (b)	None Observed	—
	(Table 18)	I_{eo} (b)	None Observed	—
	(Table 18)	I_p	None Observed	—

(a) Engineering estimate without regard to application
(b) Pre- and post-irradiation measurements only

Table 1c. Catastrophic Failure Summary

Device	Bias Condition	Catastrophic Failure (a)
2N3484 (Annular Planar Construction)	Zero bias	3 of 3 failed by 6 x 10^{15} e/cm^2
	12V bias	2 of 3 failed by 1 x 10^{16} e/cm^2
	20V bias	None of 3 failed by 1 x 10^{16} e/cm^2
2N3980 (Diffused Planar Construction)	Zero bias	2 of 3 failed by 7 x 10^{15} e/cm^2
	12V bias	1 of 3 failed by 1 x 10^{16} e/cm^2
	20V bias	None of 3 failed by 1 x 10^{16} e/cm^2
2N1671B (Grown Junction Construction)	Zero bias	3 of 3 failed by 3 x 10^{15} e/cm^2
	12V bias	3 of 3 failed by 7 x 10^{15} e/cm^2
	20V bias	3 of 3 failed by 5 x 10^{15} e/cm^2

(a) V_v dissappears and part no longer acts as unijunction device (see tables in Section V for levels where each device failed).

III. DEVICE DESCRIPTION

The three unijunction transistors whose terminal characteristics were measured on this program are identified in Table 1. The 2N1671B unit is a silicon unijunction transistor in which the p-n junction is grown in the material during the fabrication process. The 2N3780 unit is a planar device with the p-n junction diffused into an n-type substrate. The 2N3484 unit is an annular planar device which has a series of p-type rings on n-type material. The annular construction of this latter unit results in a device type whose characteristics are more readily reproducible from unit to unit in the manufacturing process. The basic characteristics of the three device types being considered here are identified in Table 2. A typical characteristic curve for the class of devices under consideration is presented in Fig. 1.

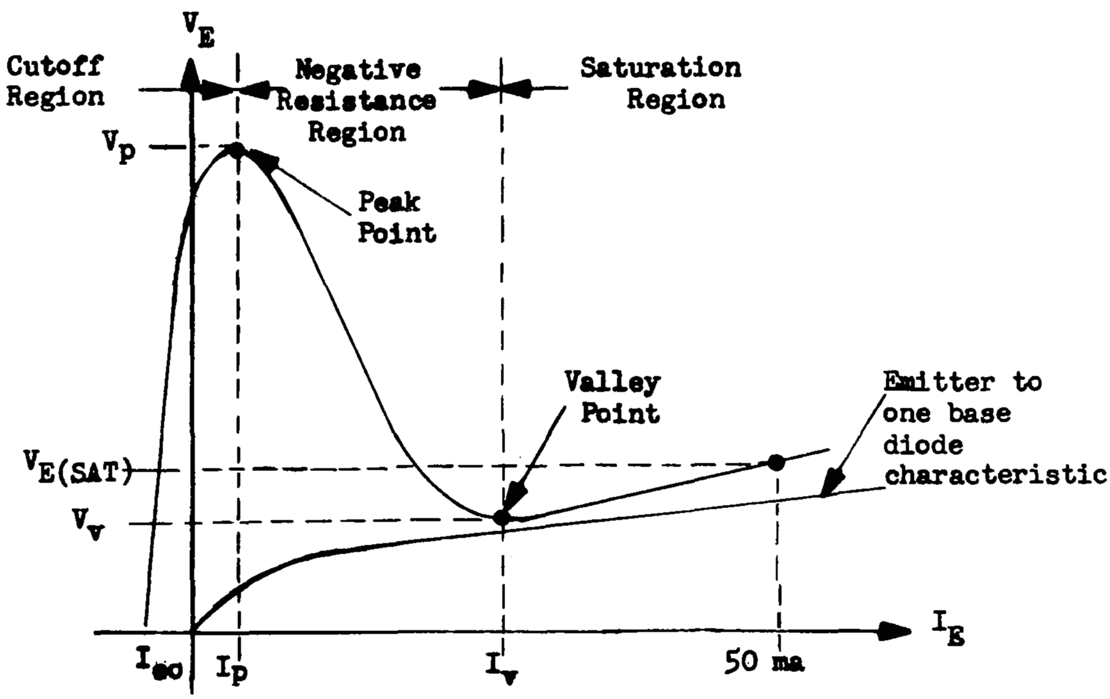


Figure 1. Typical Characteristic Curve for Unijunction Transistor.

Table 2. Basic Device Characteristics

Parameter		2N1671B		2N3980		2N3484	
		Max.	Min.	Max.	Min.	Max.	Min.
Interbase Resistance, R_{BB}	Kohm	9.1	4.7	8	4	9.1	6.2
Peak Point Voltage, V_p	V	—	3.0	—	6	—	—
Interbase Modulated Current, $I_{B2\ (mod)}$	ma	22	6.8	—	12	15	—
Emitter Saturation Voltage, $V_{E\ (sat)}$	V	5	—	3	—	5.0	—
Intrinsic Stand-off Ratio, η	—	0.62	0.47	0.82	0.68	0.85	0.70
Emitter Reverse Current, I_{eo}	μa	-0.2	—	10^{-3}	—	0.2	—
Peak Point Emitter Current, I_p	μa	6	—	2	—	5.0	—

IV. TESTING METHODS

A. Pre and Post Irradiation Measurements

All test parts were characterized prior to the electron irradiation and after irradiation, and selected in-situ measurements were made. Test circuits were assembled for each type of measurement performed. The test circuits used are identified and discussed below.

1. Interbase Resistance (R_{BB}). Interbase resistance measurements were made by determining the voltage drop across the transistor base due to the injection of a constant current into Base 2. Currents of 0.01 ma and 0.1 ma were used. The smaller current value was chosen to limit the voltage drop across the transistors to a few volts as the interbase resistance increased following irradiation. The value of interbase resistance is the ratio of measured voltage drop to the value of injected current. The test circuit used is shown in Fig. 2.

2. Intrinsic Stand-off Ratio (η). This measurement was made using the circuit shown in Fig. 3, a standard circuit according to military specification MIL-S-38103 (USAF). In this circuit, the unijunction transistor operates as a relaxation oscillator. The peak voltage at the emitter during operation is measured as a percentage of the supply voltage, this percentage being the stand-off ratio η. A 100 microamp meter is first adjusted to read full scale when the calibrate button connects the measuring circuit to the bias supply, the deflection during operation being read as a fraction of full scale.

3. Peak Point Emitter Current (I_p). This quantity was measured using the circuit of Fig. 4, a standard circuit according to military specification MIL-S-38103(USAF). With this circuit, R_1 is adjusted until the transistor fires, as indicated by a sudden increase in ammeter deflection. The current reading just prior to this point is considered to be I_p. One difficulty in using this circuit was found, as the setting of potentimeter R_1 was changed, the current indicated on the meter is the charging current of the 0.2 microfarad capacitor. Initially, the peak point current is very small, and tended to be obscured by the charging current. Very slow adjustment of R1 is thus required in order to determine I_p of the devices under test.

4. Emitter Reverse Current (I_{eo}). This parameter was measured using the test circuit of Fig. 5, with a bias supply of 10 volts.

5. Valley Voltage (V_v) Peak Point Voltage (V_p), and Emitter Saturation Voltage (V_E (sat)). Valley voltage, peak point voltage, and emitter saturation voltage were measured using the circuit of Fig. 6. Interbase voltage was ten volts and V_E (sat) was read at a 50 milliamp emitter current. The data were recorded by photographic techniques from the oscilloscope trace.

B. In-Situ Measurements

A test system was constructed to perform measurements on the irradiated unijunction transistors. Three test runs were conducted, the first with zero bias on the devices during irradiation, the second with an interbase bias of of 10 volts, and the third with an interbase bias of 20 volts. Nine devices, three each of three types, were irradiated simultaneously in a linear array 5 inches long by 1 inch wide in each test run. The accelerator was operated in a sweep mode. The parts were mounted on a phenolic board supported in the electron beam, with two conductor shielded cables connecting the parts to the test circuits. A blower was used throughout the test to cool the parts.

The following parameters of each device were measured after each radiation exposure.

Interbase resistance, R_{BB}
Intrinsic stand-off ratio, η
Valley voltage, V_v
Peak point voltage, V_p
Emitter saturation voltage, $V_{E\,(sat)}$

Fig. 8 is a schematic diagram of the test panel and interconnections to measuring instruments. During each radiation exposure, Switches S-1 through S-9, each associated with a different unijunction transistor, connected the parts to the bias supply used during irradiation. As measurements are conducted, Switch S-10 connects the devices under test to one of four test configurations. In each position of S-10, Switches S-1 through S-9 are used to successively connect the transistors to Switch 10 and the appropriate test circuit. Measurements could be performed rapidly after each irradiation, with negligible time for annealing to occur.

C. Dosimetry

Dosimetry measurements were conducted by GSFC using a Faraday cup situated immediately below the samples, and within the sweep of the beam. The fluence levels used for each run are tabulated in Table 3.

D. Equipment List

The items of equipment used during the experimental part of the program are identified below:

(1) Princeton Power Supply Type TC-100.2AR, S/N 126

(2) Cubic Corporation Digital Voltmeter Type V-70, S/N 304

(3) Hewlett Packard Voltmeter-Ohmmeter-Ammeter Type 412A, S/N 424-10531

(4) Tektronix Type 575 Curve Tracer, S/N 008029

(5) Tektronix Type 519 Camera with case, S/N 001053

(6) Two Hewlett Packard Power Supplies Type 721A (Supplied by Goddard SPC)

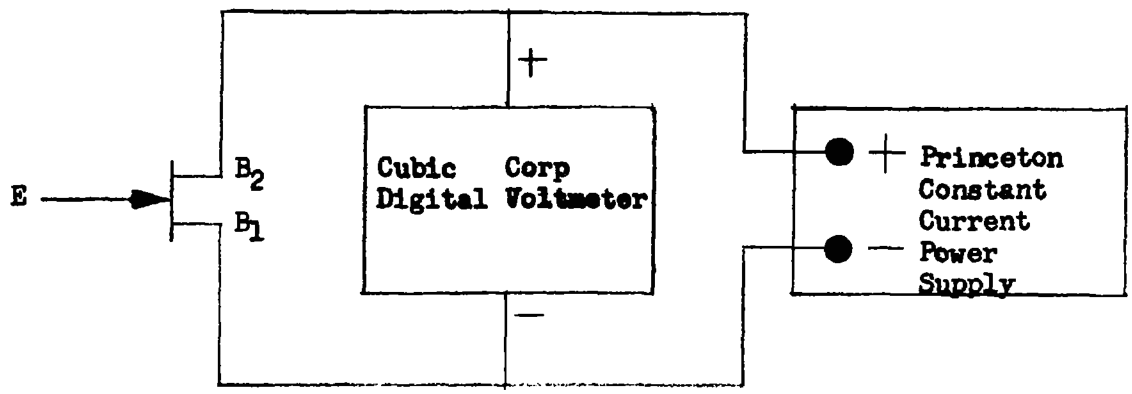


Figure 2. Test Circuit for Measuring Interbase Resistance.

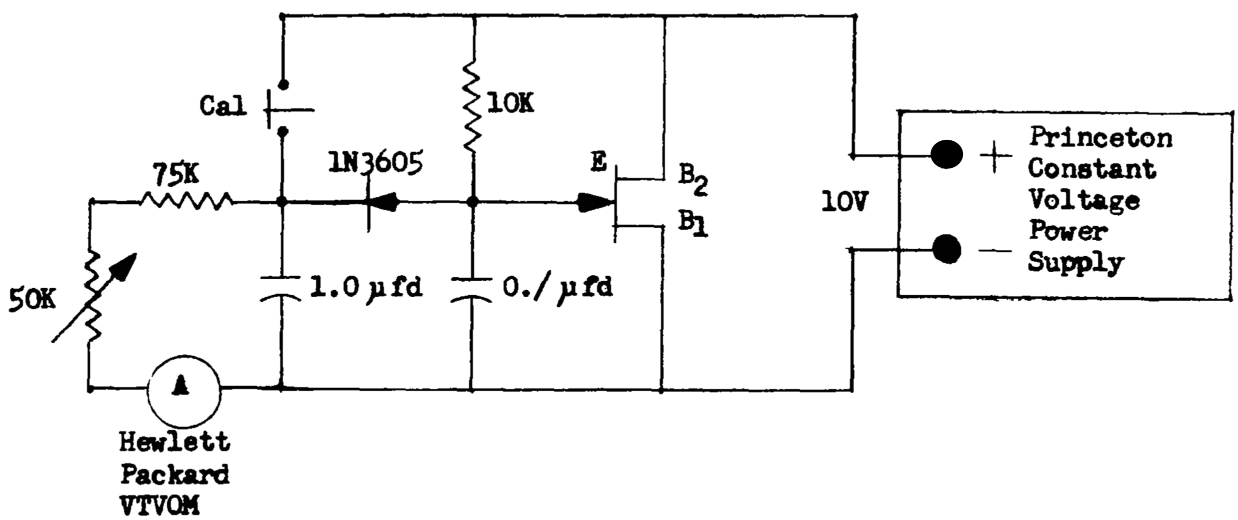


Figure 3. Test Circuit for Measurement of Intrinsic Standoff Ratio.

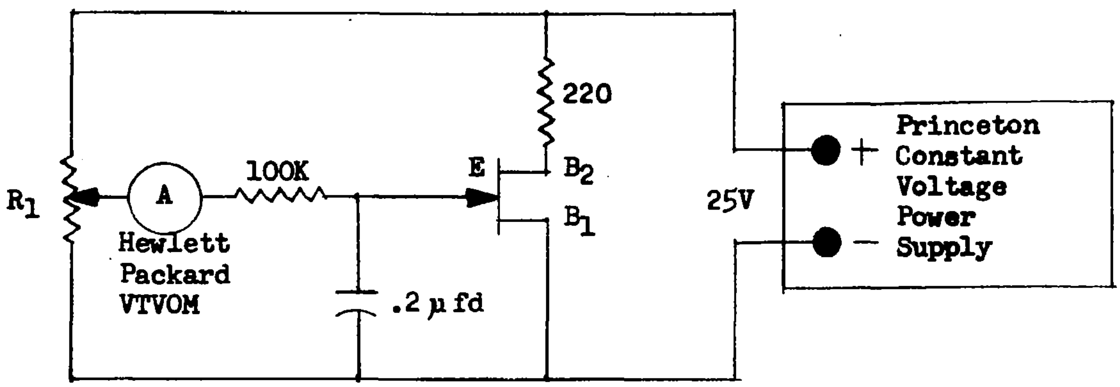


Figure 4. Test Circuit for Measurement of Peak Point Emitter Current.

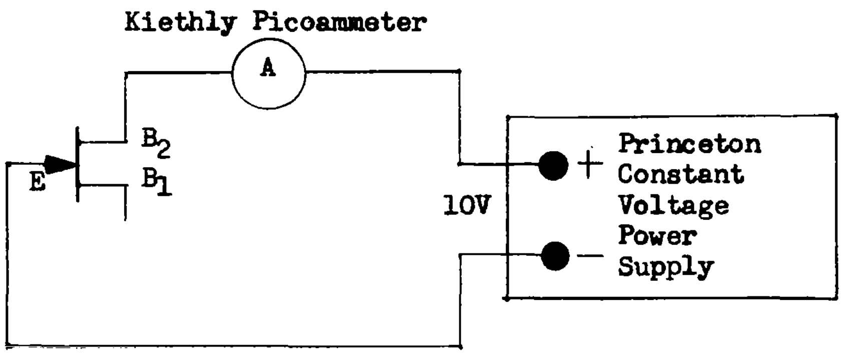


Figure 5. Test Circuit for Measuring Emitter Reverse Current.

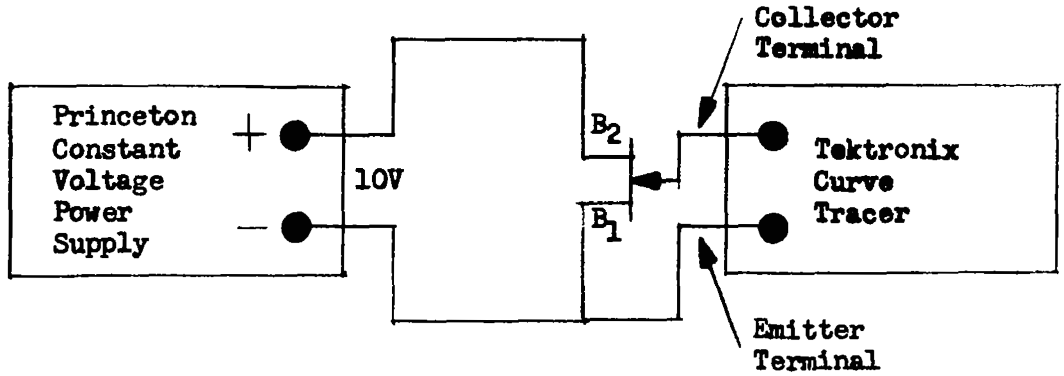


Figure 6. Test Circuit for Measuring V_V, V_P, and $V_{E(SAT)}$.

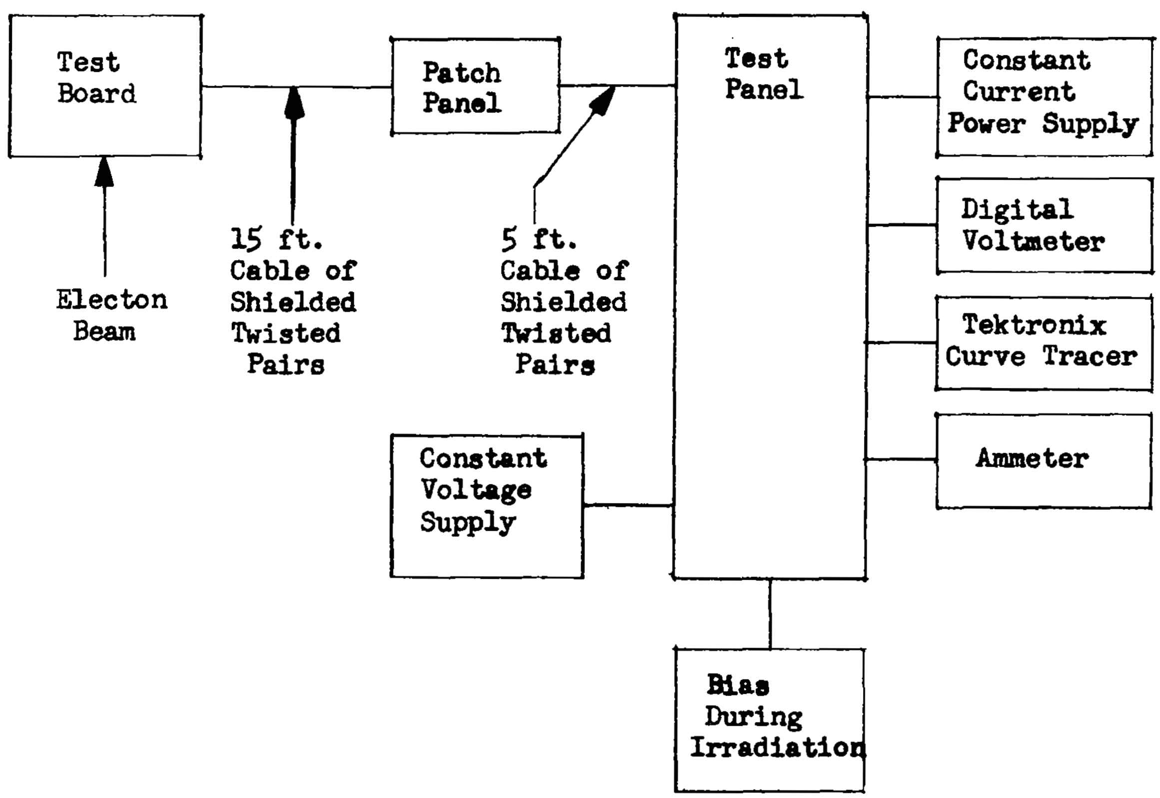
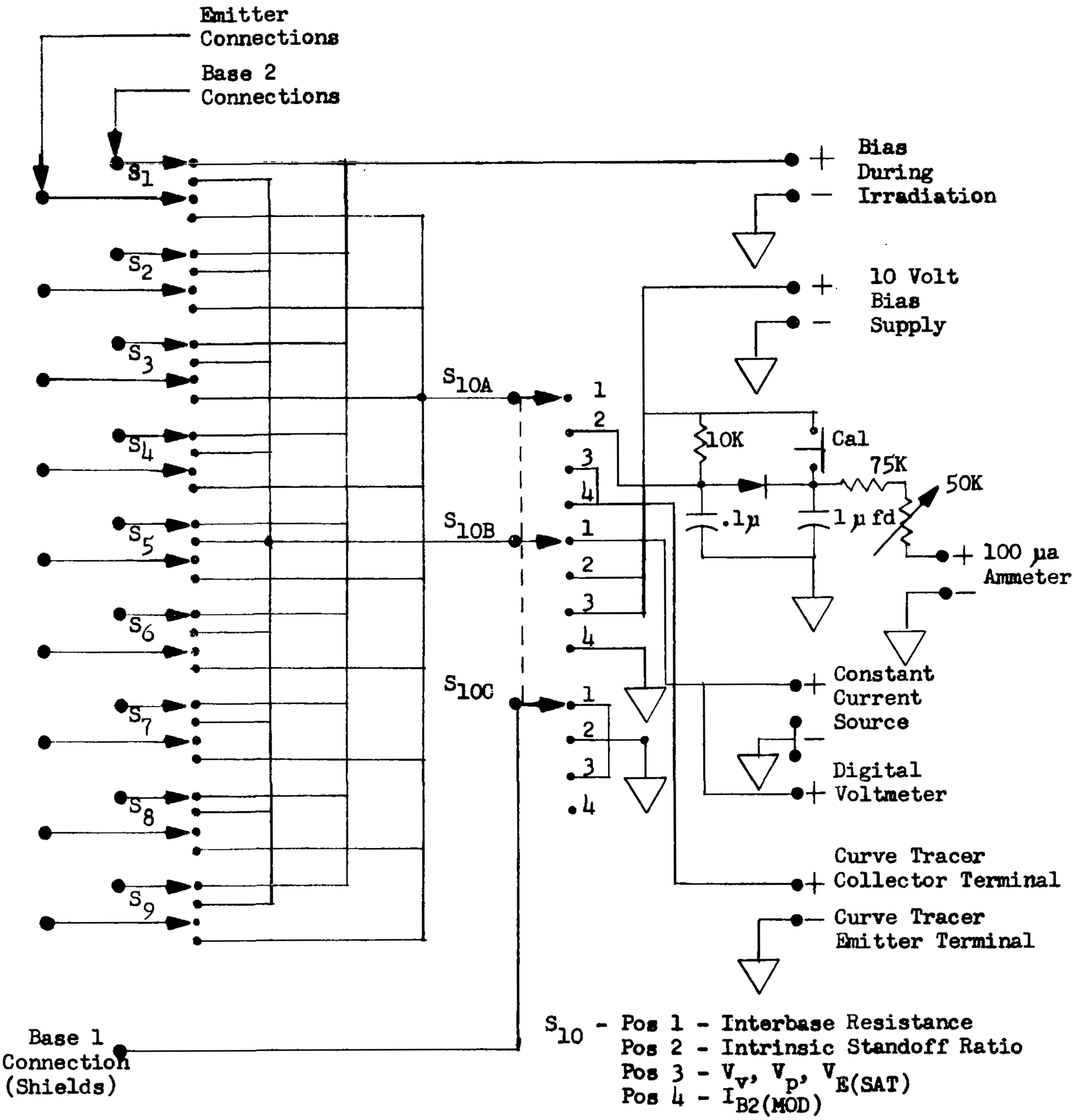


Figure 7. Block Diagram of In Situ Test Set Up.



S_1 through S_9 shown in position used during irradiation

Figure 8. Schematic Diagram of Control Panel for Test.

Table 3 . Electron Fluxes and Fluences Used (E = 1.5 Mev)

Unbiased Devices		12V Bias		20V Bias	
Flux	Fluence	Flux	Fluence	Flux	Fluence
1.0×10^{10}	1.0×10^{12}	1.0×10^{10}	1.25×10^{12}	1.0×10^{10}	1.0×10^{12}
1.0×10^{10}	1.0×10^{13}	1.0×10^{10}	1.25×10^{13}	1.0×10^{10}	1.0×10^{13}
1.0×10^{11}	1.0×10^{14}	1.0×10^{11}	1.0×10^{14}	1.0×10^{11}	3.4×10^{14}
2.85×10^{11}	1.0×10^{15}	7.0×10^{11}	1.0×10^{15}	7.0×10^{11}	1.0×10^{15}
2.85×10^{11}	3×10^{15}	7.0×10^{11}	3.0×10^{15}	7.0×10^{11}	3.0×10^{15}
4.0×10^{11}	5×10^{15}	7.0×10^{11}	5.0×10^{15}	7.0×10^{11}	5.0×10^{15}
7.6×10^{11}	6×10^{15}	7.0×10^{11}	7.0×10^{15}	7.0×10^{11}	7.0×10^{15}
9.6×10^{11}	7×10^{15}	7.0×10^{11}	1.0×10^{16}	7.0×10^{11}	1.0×10^{16}

V. MEASURED DATA

The data presented in this section are accumulated from measurements taken during irradiation at the NASA-GSFC Radiation Effects Laboratory, and pre- and post-irradiation measurements at the Martin Company Radiation Effects Laboratory in Baltimore. Tables 4, 5 and 6 present preirradiation data on 2N1671B, 2N3980 and 2N3484, respectively; Table 3 identifies the electron fluences levels used during the tests; Tables 7, 8 and 9 show in-situ data taken on devices being irradiated in an unbiased condition, with tests being conducted at 10V bias; Tables 10, 11 and 12 show a similar set of devices irradiated with a bias level of 12V with measurements being taken using a 10V positive bias; Tables 13, 14 and 15 show devices irradiated with a 20V bias and measured at 10V bias; Tables 16, 17 and 18 show post-irradiation measurements of I_P and I_{eo} taken at 10V bias; and Table 19 presents data on $I_{B2\ (mod)}$. For ease of presentation selected tables are divided into two parts (a and b) and in these instances the fluence levels of the former also apply to the latter.

Table 4 . Preirradiation Data on 2N1671B Devices at 10V Bias

Device Number	(R_{BB}) (K-ohm) .01 ma	(R_{BB}) (K-ohm) .1 ma	(V_V) (Volts)	(V_P) (Volts)	$(V_E\,(sat))$ (Volts)	η	(I_{eo}) (Amps)	(I_P) (Amps)
1	5.8	5.58	1.9	6.4	2.5	.580	4.5×10^{-10}	All $< 5 \times 10^{-8}$ Amps
2	6.9	6.76	1.9	6.3	2.4	.570	6.4×10^{-9}	
3	5.2	5.0	1.9	6.7	2.2	.610	2.95×10^{-8}	
4	6.8	6.68	1.8	6.2	2.1	.560	3.7×10^{-9}	
5	7.8	7.53	2.8	6.6	3.2	.605	2.2×10^{-8}	
6	6.0	5.85	2.9	6.7	3.4	.615	1.74×10^{-9}	
7	6.5	6.34	2.0	5.8	2.4	.530	1.15×10^{-9}	
8	8.2	8.07	1.7	6.1	2.1	.555	8×10^{-11}	
9	6.4	6.23	1.9	6.6	2.5	.605	1.25×10^{-6}	
10	7.2	7.07	2.0	6.0	2.4	.555	1.2×10^{-10}	
11	6.6	6.38	1.9	6.4	2.4	.575	6.4×10^{-11}	
12	5.2	5.06	2.0	5.5	2.4	.495	3.4×10^{10}	

Table 5 . Preirradiation Data on 2N3980 Devices at 10V Bias

Device Number	R_{BB} (K-ohm) .01 ma	R_{BB} (K-ohm) .1 ma	V_V (Volts)	V_p (Volts)	V_E (sat) (Volts)	η	I_{eo} (10^{-11} amp)	I_p (amp)
1	5.8	5.7	1.3	7.6	1.7	.760	5.4	All $< 5 \times 10^{-8}$ amp
2	4.5	4.39	1.4	7.6	2.6	.800	6.1	
3	7.3	7.25	1.4	8.3	1.7	.802	3.5	
4	4.6	4.45	1.3	7.6	1.8	.730	3.5	
5	6.6	6.5	1.3	8.0	1.6	.772	8.2	
6	4.5	4.45	1.5	7.8	1.9	.735	5.2	
7	5.6	5.64	1.3	7.6	1.9	.748	6.2	
8	7.5	7.33	1.6	8.0	1.9	.760	7.4	
9	4.5	4.38	1.3	7.6	1.8	.720	4.0	
10	6.9	6.8	1.6	7.9	2.0	.745	9.5	
11	5.9	5.8	1.3	8.0	1.6	.765	3.8	
12	6.8	6.59	1.3	8.2	1.6	.785	2.7	

Table 6 . Preirradiation Data on 2N3484 **Devices at 10V Bias**

Device Number	R_{BB} (K-ohm) .01 ma	R_{BB} (K-ohm) .1 ma	V_V (Volts)	V_p (Volts)	V_E (sat) (volts)	η	I_{eo} (10^{-10} amp)	I_p (amp)
1	5.8	5.58	1.9	7.8	2.8	.730	4.9	All $< 5 \times 10^{-8}$ amp
2	6.9	6.76	2.0	7.9	2.1	.730	79	
3	5.2	5.0	4.4	8.8	4.4	.810	25	
4	6.8	6.68	2.1	8.1	2.2	.750	4.2	
5	7.8	7.53	2.1	7.9	2.2	.750	7.5	
6	6.0	5.85	1.4	8.2	2.1	.770	4.8	
7	6.5	6.34	1.5	7.9	2.1	.740	2.7	
8	8.2	8.07	1.3	8.2	1.9	.760	4.6	
9	6.4	6.23	2.7	8.0	4.7	.750	3.9	
10	7.2	7.07	1.5	7.8	2.2	.720	4.5	
11	6.6	6.38	1.4	8.4	1.9	.780	2.2	
12	5.2	5.06	1.7	7.9	2.5	.735	8.7	

Table 7a. IN SITU Data on 2N1671B (Devices 4, 5 and 6) Exposed at OV Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (.01 ma) (K-ohm) 4	5	6	Avg.	R_{BB} (.1 ma) (K-ohm) 4	5	6	Avg.
1.0×10^{12}	7.	7.4	5.7	6.7	6.89	7.39	5.68	6.65
1.0×10^{13}	7.1	7.3	5.8	6.7	7.03	7.23	5.76	6.67
1.0×10^{14}	8.0	8.4	7.3	7.9	7.97	8.36	7.29	7.87
1.0×10^{15}	90.3	64.62	16.8[1]	77.4	—	—	—	—
3.0×10^{15}	1290.[2]	6407.[2]	6000.[3]	—	—	—	—	—
5.0×10^{15}	394.[3]	760.[3]	~7000.[3]	—	—	—	—	—
6.0×10^{15}	3000.[3]	8740.[3]	6400.[3]	—	—	—	—	—
7.0×10^{15}	—	—	—	—	—	—	—	—
All Night Anneal	280.[3]	770.[3]	5214.[3]	—	—	—	—	—

(1) Measured at .005 ma and not included in average
(2) Measured at .002 ma and not included in average
(3) Measured at .001 ma and not included in average

Table 7b.

V_V (volts)				V_P (volts)				V_E (volts) (sat)				η			
4	5	6	Avg.	4	5	6	Avg.	4	5	6	Avg.	4	5	6	Avg.
2.8	2.8	3.0	2.9	6.3	6.7	6.8	6.6	2.2	3.3	3.4	3.0	.565	.605	.615	.594
1.9	3.0	3.2	2.7	6.3	6.7	6.8	6.6	2.3	3.4	3.6	3.1	.57	.605	.615	.597
2.7	4.2	5.3	4.1	6.2	6.6	6.9	6.6	3.4	5.2	6.9	5.2	.565	.605	.625	.599
5.2	5.6	--	5.4	5.6	6.4	--	6.0	12.4	12.8	13.6	12.9	.425	.490	.780	.743
--	--	--	--	--	--	--	--	13.6	13.6	13.6	13.6	.650	.825	.750	.703
--	--	--	--	--	--	--	--	14.6	14.8	16.4	15.5	.635	.765	.71	.682
--	--	--	--	--	--	--	--	18.2	19.4	17.0	18.2	.615	.740	.690	.680
--	--	--	--	--	--	--	--	17.16	19.4	17.2	17.9	.620	.735	.685	.662
--	--	--	--	--	--	--	--	--	--	--	--	.595	.715	.675	--

Table 8a. IN SITU Data on 2N3980 (Devices 4, 5 and 6) Exposed at 0V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (K-ohm) .01 ma				.1 ma				V_V (volts)			
	4	5	6	Avg.	4	5	6	Avg.	4	5	6	Avg.
1.0×10^{12}	4.0	5.7	4.0	4.6	4.0	5.65	3.98	4.54	1.4	1.3	1.5	1.4
1.0×10^{13}	3.4	4.8	3.4	3.9	3.36	4.78	3.32	3.49	1.3	1.3	1.4	1.3
1.0×10^{14}	2.7	3.5	2.6	2.9	2.64	3.53	2.63	2.90	1.3	1.3	1.4	1.3
1.0×10^{15}	2.7	4.0	2.7	3.1	2.64	4.02	3.66	3.11	2.2	2.0	2.5	2.2
3.0×10^{15}	3.0	43.0*	3.0	3.0	3.01	42.12*	2.98	3.00	4.1	—	4.6	4.4
5.0×10^{15}	5.4	179.*	5.6	5.5	5.38	—	5.56	3.65	2.2	—	2.3	2.2
6.0×10^{15}	4.2	311.*	5.2	4.7	4.19	—	5.14	3.11	4.2	—	4.4	4.3
7.0×10^{15}	5.4	524.*	8.1	6.7	5.31	—	8.07	4.46	4.0	—	—	4.0
All Night Anneal	5.6	550.*	8.7	7.2	5.59	—	8.63	4.74	5.6	—	—	5.6

Note: *Not included in average

Table 8b.

V_P (volts)				V_E (sat) (volts)				η			
4	5	6	Avg.	4	5	6	Avg.	4	5	6	Avg.
7.5	7.8	7.6	7.6	1.8	1.6	1.8	1.7	.705	.740	.710	.718
6.8	7.2	7.0	7.0	1.7	1.6	1.9	1.7	.635	.675	.640	.650
5.9	5.9	6.0	5.9	1.8	1.6	2.0	1.8	.550	.550	.550	.550
5.7	5.0	5.8	5.5	3.2	3.1	3.6	3.3	.525	.455	.525	.502
5.5	--	5.4	5.4	5.8	--	6.7	6.2	.495	.120	.480	.366
2.5	--	2.4	2.4	6.8	--	8.5	7.6	.625	.220	.605	.484
4.6	--	4.4	4.5	15.2	--	18.0	16.6	.380	.145	.345	.290
4.4	--	--	4.4	16.6	--	--	16.6	.340	.150	.280	.257
5.0	--	--	5.0	11.4	--	--	11.4	.340	.160	.280	.260

Table 9a. IN SITU Data on 2N3484 (Devices 4, 5 and 6) Exposed at OV Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (K-ohm)				R_{BB} (K-ohm)				V_V (volts)			
	4	5	6	Avg.	4	5	6	Avg.	4	5	6	Avg.
1.0×10^{12}	5.8	6.4	5.9	6.0	5.80	6.43	5.91	6.05	2.2	2.1	1.4	1.9
1.0×10^{13}	5.7	6.4	5.9	6.0	5.80	6.42	5.92	6.05	2.2	2.1	1.4	1.9
1.0×10^{14}	5.9	6.5	6.0	6.1	5.97	6.58	6.03	6.10	2.5	2.5	1.6	2.2
1.0×10^{15}	6.8	7.3	6.8	7.0	6.88	7.43	6.86	7.06	6.8	4.8	2.8	4.8
3.0×10^{15}	8.8	8.9	8.3	8.7	8.89	8.97	8.40	8.75	—	3.3	5.6	3.0
5.0×10^{15}	11.2	11.1	10.4	10.9	11.24	11.18	10.43	10.95	—	6.6	6.8	6.7
6.0×10^{15}	10.3	10.1	9.3	9.9	10.37	10.23	9.41	10.00	—	—	6.8	6.8
7.0×10^{15}	10.7	10.5	9.6	10.3	10.77	10.57	9.73	10.36	—	—	—	—
All Night Anneal	10.5	10.4	9.6	10.2	10.72	10.5	9.70	10.31	—	—	—	—

Table 9b.

Avg.	V_p (volts)				V_E (sat) (volts)				η			
	4	5	6	Avg.	4	5	6	Avg.	4	5	6	Avg.
1.9	8.3	8.1	8.4	8.3	2.3	2.2	2.2	2.2	.765	.750	.775	.764
1.9	8.3	8.1	8.3	8.2	2.3	2.3	2.0	2.2	.770	.755	.780	.770
2.2	8.1	8.0	8.3	8.1	2.6	2.6	2.3	2.5	.750	.740	.770	.753
4.8	7.6	7.6	7.8	7.7	8.0	5.6	5.2	6.3	.695	.700	.720	.705
3.0	—	3.5	7.2	5.4	—	—	14.4	14.4	.610	.620	.640	.620
6.7	—	6.6	6.8	6.7	—	—	—	—	.655	.680	.695	.677
6.8	—	—	6.8	6.8	—	—	—	—	.630	.635	.650	.638
—	—	—	—	—	—	—	—	—	.615	.640	.650	.635
—	—	—	—	—	—	—	—	—	.615	.640	.650	.635

Table 10a. IN SITU Data on 2N1671B (Devices 7, 8 and 9) Exposed at 12V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (.01 ma) (K-ohm)				R_{BB} (.1 ma) (K-ohm)			
	7	8	9	Avg.	7	8	9	Avg.
1.25×10^{12}	5.4	6.3	4.9	16.6	5.34	6.27	4.38	5.29
1.25×10^{13}	4.8	5.5	4.2	14.5	4.72	5.13	4.08	4.64
1.0×10^{14}	5.0	5.5	4.0	4.5	4.88	5.35	3.94	4.72
1.0×10^{15}	12.2	35.2	9.3	56.7	12.44	36.63	9.48	10.95
3.0×10^{15}	88.	146.6	32.5	88.7	--	--	31.88	31.88
5.0×10^{15}	115.	230.	38.1	128.0	--	--	36.57	36.57
7.0×10^{15}	148.	376.	52.6	192.2	--	--	55.04	55.04
1.0×10^{16}	221.	644.	64.8	310.3	--	--	69.55	69.55
All Night Anneal	286.2	540.	125.5	317.2	--	--	--	--

Table 10a.

V_V (volts)				V_D (volts)				V_E (sat) (volts)				η			
7	8	9	Avg.	7	8	9	Avg.	7	8	9	Avg.	7	8	9	Avg.
1.8	1.4	1.4	1.5	4.6	5.4	5.4	5.1	2.2	2.0	2.0	2.1	.380	.470	.430	.427
1.4	1.4	1.4	1.4	4.1	5.0	4.8	4.6	2.0	1.9	2.0	2.0	.345	.440	.440	.399
1.6	1.6	1.5	1.6	4.2	4.8	4.5	4.5	2.2	2.1	2.2	2.2	.370	.420	.390	.394
3.8	4.1	3.8	3.9	4.5	6.0	4.2	4.9	—	—	—	—	.335	.365	.330	.344
—	6.4	4.4	5.4	—	7.0	6.4	6.7	—	14.6	13.2	13.9	.735	.595	.410	.580
4.0	—	—	4.0	7.2	—	—	7.2	—	17.8	14.4	16.1	.465	.600	.445	.507
—	—	—	—	—	—	—	—	—	—	15.0	15.0	.480	.600	.460	.513
—	—	—	—	—	—	—	—	—	—	16.6	16.6	.495	.600	.455	.517
—	—	—	—	—	—	—	—	—	—	18.0	18.0	.560	.640	.605	.602

Table 11a. IN SITU Data on 2N3980 (Devices 7, 8 and 9) Exposed at 12V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (.01 ma) (K-ohm)				R_{BB} (.01 ma) (K-ohm)			
	7	8	9	Avg.	7	8	9	Avg.
1.25×10^{12}	5.1	6.4	4.0	5.2	4.94	6.33	3.9	5.06
1.25×10^{13}	4.4	5.6	3.6	4.5	4.28	5.45	3.52	4.42
1.0×10^{14}	4.2	5.3	3.6	4.4	4.02	5.11	3.41	4.18
1.0×10^{15}	4.0	5.2	3.6	4.3	3.88	5.11	3.5	4.16
3.0×10^{15}	4.4	6.1	4.0	4.8	4.31	5.96	3.94	4.74
5.0×10^{15}	4.3	6.1	4.0	4.8	4.23	6.0	3.94	4.06
7.0×10^{15}	4.9	7.7	4.9	5.8	4.89	7.69	4.88	5.82
1.0×10^{16}	8.7	15.8	11.1	11.9	8.38	15.99	11.11	11.83
All Night Anneal	8.2	15.1	9.7	11.0	8.22	15.28	9.75	11.08

Table 11b.

V_v (volts)				V_p (volts)				V_E (sat) (volts)				η			
7	8	9	Avg.	7	8	9	Avg.	7	8	9	Avg.	7	8	9	Avg.
1.4	1.6	1.6	1.5	7.2	7.8	7.4	7.5	1.8	2.0	1.8	1.9	.720	.730	.700	.720
1.2	1.5	1.3	1.3	6.8	7.0	7.0	6.9	1.8	2.0	1.8	1.9	.670	.670	.660	.666
1.2	1.5	1.4	1.4	6.6	6.7	6.8	6.7	1.7	2.0	1.8	1.8	.640	.640	.640	.640
2.1	2.2	2.1	2.1	6.5	6.6	6.7	6.6	3.0	3.3	3.1	3.1	.615	.615	.635	.622
3.6	3.6	3.2	3.5	6.2	6.2	6.2	6.2	7.4	7.8	6.6	7.3	.585	.575	.615	.592
4.6	4.4	4.8	4.6	5.8	5.6	6.0	5.8	14.0	15.2	13.0	14.0	.515	.485	.545	.515
4.6	4.2	4.6	4.5	5.0	4.6	5.2	4.9	19.6	20.4	18.6	19.6	.400	.360	.405	.388
—	6.0	6.4	6.4	—	6.0	6.8	6.4	—	—	—	—	.300	.270	.260	.276
—	5.6	—	5.6	—	5.6	—	5.6	16.6	—	—	16.6	.315	.280	.275	.290

Table 12a. IN SITU Data on 2N3484 (Devices 7, 8 and 9) Exposed at 12V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (.01 ma) (K-ohm)				R_{BB} (.1 ma) (K-ohm)			
	7	8	9	Avg.	7	8	9	Avg.
1.25×10^{12}	5.8	5.8	7.5	6.4	5.77	5.73	7.56	6.35
1.25×10^{13}	5.8	5.8	7.5	6.4	5.76	5.73	7.49	6.33
1.0×10^{14}	6.0	5.9	7.7	6.0	5.83	5.77	7.66	6.42
1.0×10^{15}	6.5	6.4	8.4	7.1	6.41	6.28	8.5	7.06
3.0×10^{15}	7.6	7.4	10.1	8.4	7.53	7.27	10.16	8.32
5.0×10^{15}	8.1	7.9	11.0	9.0	8.06	7.75	11.07	8.96
7.0×10^{15}	8.6	8.4	11.7	9.6	8.59	8.24	11.9	9.24
1.0×10^{16}	9.4	9.2	12.7	10.4	9.35	9.07	13.04	10.45
All Night Anneal	9.4	9.3	12.8	10.5	9.43	9.25	12.92	10.53

Table 12b.

V_V (volts)				V_P (volts)				V_E (sat) (volts)				η			
7	8	9	Avg.	7	8	9	Avg.	7	8	9	Avg.	7	8	9	Avg.
1.6	1.4	2.8	1.9	8.2	8.4	8.2	8.3	2.0	1.8	2.8	2.2	.76	.775	.76	.765
1.6	1.4	2.8	1.9	8.2	8.4	8.2	8.3	2.0	2.0	2.8	2.3	.765	.775	.77	.770
1.6	1.4	3.0	2.0	8.2	8.4	8.2	8.3	2.0	2.0	3.0	2.3	.765	.775	.755	.765
3.0	2.6	4.9	3.5	7.8	8.0	7.7	7.8	4.7	4.3	12.1	7.0	.735	.745	.720	.734
5.2	5.2	7.0	5.8	7.2	5.6	7.0	6.6	22.0	—	18.2	20.1	.675	.695	.640	.670
6.0	6.6	5.6	6.1	7.2	7.4	—	7.3	—	—	12.0	12.0	.66	.680	.640	.660
6.4	7.2	—	6.8	7.2	7.2	—	7.2	—	—	—	--	.645	.670	.645	.654
6.8	—	—	6.8	6.8	—	—	6.8	—	—	—	--	.635	.685	.645	.655
6.8	—	—	6.8	7.0	—	—	7.0	—	—	—	--	.635	.685	.645	.655

Table 13a. IN SITU Data on 2N1671E (Devices 10, 11 and 12) Exposed at 20V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (K-ohm) .01 ma				R_{BB} (K-ohm) .1 ma				V_V			
	10	11	12	Avg.	10	11	12	Avg.	10	11	12	Avg.
1.0×10^{12}	6.4	6.3	5.3	6.0	6.3	6.02	5.1	5.81	1.8	1.8	2.0	1.9
1.0×10^{13}	5.7	5.7	5.3	5.6	5.34	5.95	5.1	5.29	1.7	1.7	1.8	1.7
3.4×10^{14}	8.0	8.5	11.2	9.2	7.64	8.4	10.96	9.00	3.0	2.7	3.0	2.9
1.0×10^{15}	23.1	25.7	124.1	86.4	24.4	26.99	--	25.69	3.6	3.6	4.2	3.8
3.0×10^{15}	105.2	40.9	430.6	19.2	--	45.38	--	45.38	4.0	--	--	4.0
5.0×10^{15}	207.6	43.6	519.0	256.	--	51.68	--	51.68	--	--	--	--
7.0×10^{15}	320.0	47.2	476.7	285.	--	56.99	--	56.99	--	--	--	--
1.0×10^{16}	509.4	62.0	479.6	350.	--	78.89	--	78.89	--	--	--	--

Table 13b.

V_P (volts)				V_E (sat) (volts)				η			
10	11	12	Avg.	10	11	12	Avg.	10	11	12	Avg.
5.2	5.5	5.0	5.2	2.4	2.4	2.5	2.4	.470	.490	.435	.465
4.3	4.3	4.2	4.3	2.3	2.3	2.4	2.3	.375	.380	.365	.374
5.1	4.1	5.0	4.8	4.6	4.2	4.6	4.5	.450	.345	.440	.412
5.1	5.8	6.5	5.8	—	—	—	—	.310	.285	.370	.322
9.0	—	—	9.0	—	—	11.6	11.6	.440	.360	.480	.426
—	—	—	—	14.6	13.2	12.4	13.4	.435	.350	.465	.417
—	—	—	—	16.0	14.0	12.4	14.1	.435	.345	.460	.414
—	—	—	—	—	14.8	12.8	13.8	.420	.325	.460	.402

Table 14a. IN SITU Data on 2N3980 (Devices 10, 11 and 12) Exposed at 20V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (K-ohm) .01 ma				R_{BB} (K-ohm) .1 ma				V_V			
	10	11	12	Avg.	10	11	12	Avg.	10	11	12	Avg.
1.0×10^{12}	6.4	5.5	6.1	6.0	6.25	5.36	5.9	5.84	1.6	1.3	1.4	1.4
1.0×10^{13}	5.9	5.0	5.5	5.5	5.72	4.8	5.31	5.24	1.6	1.3	1.3	1.4
3.4×10^{14}	5.6	4.3	4.8	4.9	5.39	4.09	4.64	4.71	1.8	1.7	1.7	1.7
1.0×10^{15}	5.7	4.4	4.0	4.7	5.57	4.18	3.92	4.56	2.4	2.0	1.9	2.1
3.0×10^{15}	6.4	4.6	5.3	5.4	6.32	4.48	5.12	5.31	4.0	3.4	3.8	3.7
5.0×10^{15}	7.6	5.1	5.7	6.1	7.45	4.94	5.65	6.01	4.4	4.6	5.0	4.7
7.0×10^{15}	9.7	5.6	6.3	7.2	9.62	5.47	6.18	7.09	4.2	4.8	5.2	4.7
1.0×10^{16}	18.4	8.8	8.1	11.8	17.64	7.77	7.64	11.02	3.2	4.0	4.4	3.9

Table 14b.

V_P (volts)				V_E (sat) (volts)				η			
10	11	12	Avg.	10	11	12	Avg.	10	11	12	Avg.
7.5	7.8	7.8	7.7	2.0	1.7	1.6	1.8	.705	.745	.750	.734
7.2	7.4	7.5	7.4	2.1	1.6	1.7	1.8	.675	.710	.715	.702
6.8	6.6	7.0	6.8	2.5	2.7	2.4	2.5	.635	.615	.665	.639
6.7	6.5	6.8	6.7	3.6	2.9	2.6	3.0	.625	.610	.625	.620
6.2	6.4	6.8	6.5	8.4	6.2	6.2	6.9	.565	.585	.640	.597
5.6	6.0	6.4	6.0	16.4	11.6	12.0	13.3	.390	.545	.595	.510
4.8	5.6	6.0	5.5	—	16.8	18.2	17.5	.350	.485	.455	.430
12.0	6.2	5.0	7.7	—	23.2	—	23.2	.275	.34	.410	.342

Table 15a. IN SITU Data on 2N3484 (Devices 10, 11 and 12) Exposed at 20V Bias and Measured at 10V Bias

Electron Fluence	R_{BB} (K ohm) .01 ma				.1 ma				V_V			
	10	11	12	Avg.	10	11	12	Avg.	10	11	12	Avg.
1.0×10^{12}	6.7	6.2	7.5	6.8	6.62	6.11	7.48	6.74	1.5	1.4	1.7	1.5
1.0×10^{13}	6.7	6.2	7.4	6.8	6.55	6.08	7.39	6.67	1.6	1.4	1.7	1.6
3.4×10^{14}	7.0	6.4	7.9	7.1	6.86	6.3	7.84	7.00	1.9	1.8	2.0	1.9
1.0×10^{15}	7.3	6.8	8.4	7.5	7.22	6.65	8.34	7.40	2.5	2.2	2.7	2.5
3.0×10^{15}	8.4	7.7	9.6	8.6	8.37	7.66	9.61	8.55	4.0	4.6	4.4	4.3
5.0×10^{15}	9.0	8.4	10.4	9.3	8.97	8.27	10.31	7.18	5.0	5.6	5.6	5.4
7.0×10^{15}	9.5	8.8	10.8	9.7	9.42	8.71	10.83	9.65	5.8	6.4	6.2	6.1
1.0×10^{16}	11.4	10.6	12.3	11.4	--	9.33	11.56	10.45	6.4	6.4	6.6	6.5

Table 15b.

V_P (volts)				V_E (sat) (volts)				η			
10	11	12	Avg.	10	11	12	Avg.	10	11	12	Avg.
8.0	8.1	8.0	**8.0**	2.3	1.9	2.6	**2.3**	.735	.785	.745	**.756**
8.0	8.0	8.0	**8.0**	2.3	2.0	2.5	**2.3**	.740	.790	.75	**.760**
7.8	8.0	7.8	**7.9**	2.8	2.6	3.3	**2.9**	.725	.780	.725	**.744**
7.6	8.2	7.6	**7.8**	4.1	4.0	5.0	**4.4**	.710	.760	.7	**.723**
7.0	5.6	7.0	**6.5**	12.6	—	16.6	**14.6**	.640	.700	.665	**.667**
7.0	7.6	6.8	**7.1**	—	—	—	—	.625	.680	.615	**.640**
6.8	7.4	6.8	**7.0**	—	—	—	—	.620	.670	.605	**.632**
6.8	6.8	6.6	**6.7**	—	—	—	—	.75	.655	.595	**.615**

Table 16. Post Irradiation Measurements on 2N1671B at 10V Bias

Number	Electron Fluence	I_{eo} (10^{-9} amps)	I_P (amps)
1	0	1.0	14×10^{-8}
2	0	9.0	$< 10^{-8}$
3	0	32	"
4	7.0×10^{15}	3700	"
5	7.0×10^{15}	100	"
6	7.0×10^{15}	1400	"
7	1.0×10^{16}	77.	"
8	1.0×10^{16}	120.	"
9	1.0×10^{16}	46.	"
10	1.0×10^{16}	99	"
11	1.0×10^{16}	40	"
12	1.0×10^{16}	45	"

Note: Measurement made in Martin Laboratory

Table 17 . Post Irradiation Measurements on 2N3980 at 10V Bias

Device Number	Electron Fluence	I_{eo} (10^{-9} amps)	I_P (amps)
1	0	.048	5×10^{-8}
2	0	.065	5×10^{-8}
3	0	.026	5×10^{-8}
4	7.0×10^{15}	.081	E-B Lead Open
5	7.0×10^{15}	.3	E-B Lead Open
6	7.0×10^{15}	.3	1.0×10^{-7}
7	1.0×10^{16}	1.75	1.0×10^{-7}
8	1.0×10^{16}	1.2	2.4×10^{-7}
9	1.0×10^{16}	2.5	1.0×10^{-6}
10	1.0×10^{16}	1.5	1.0×10^{-7}
11	1.0×10^{16}	37.	5.0×10^{-7}
12	1.0×10^{16}	1.85	1.0×10^{-7}

Note: Measurements made in Martin Laboratory

Table 18. Post Irradiation Measurements on 2N3484 at 10V Bias

Device Number	Electron Fluence	I_{eo} (10^{-9} amps)	I_p (10^{-8} amps)
1	0	.51	$\sim$ 5
2	0	7.9	$\sim$ 5
3	0	2.5	$\sim$ 10
4	7.0×10^{15}	1.25	$\leq$ 5
5	7.0×10^{15}	1.2	5
6	7.0×10^{15}	1.45	5
7	1.0×10^{16}	1.75	5
8	1.0×10^{16}	1.85	5
9	1.0×10^{16}	1.45	5
10	1.0×10^{16}	1.3	5
11	1.0×10^{16}	1.45	5
12	1.0×10^{16}	1.55	$\leq$ 5

Note: Measurements made in Martin Laboratory

Table 19. Measurements of I_{B2} (mod)

Device Number	Electron Fluence	I_{B2} (Mod) at 10V Bias (na)			I_{B2} (Mod) at 20V Bias (na)		
		2N1671B	2N3980	2N3484	2N1671B	2N3980	2N3484
1	0	15.2	12.5	3.9	17.8	14.5	7.9
2	0	15.2	12.8	3.5	17.5	14.7	7.7
3	0	15.2	12.3	2.8	17.5	14.2	7.5
4	7.0×10^{15}	—	—	—	.18	$<$.02	.9
5	7.0×10^{15}	—	—	—	.09	.16	1.0
6	7.0×10^{15}	—	—	—	.01	2.6	1.1
7	1.0×10^{16}	—	—	—	.035	2.0	1.4
8	1.0×10^{16}	—	—	—	.06	1.4	1.3
9	1.0×10^{16}	—	—	—	.09	1.8	.8
10	1.0×10^{16}	—	—	—	.09	1.7	1.2
11	1.0×10^{16}	—	—	—	.28	2.4	1.5
12	1.0×10^{16}	—	—	—	.18	2.7	1.0

Note: Measurements made in Martin Laboratory

VI. DATA ANALYSIS

The measured data as tabulated in the previous section are summarized in graphical form, Figures 9 through 24, in this section of the test report. These plotted data represent averages of measurements on three devices of each type where appropriate and as indicated in Section IV. The curves through the data points in the referenced graphs represent a visual fit. The emphasis on this program was placed on obtaining experimental data of device performance when exposed to 1.5 Mev electrons and no attempt is made to relate measured changes in device terminal properties to microscopic material or junction properties of the device. The following paragraphs identify where the data for each parameter are plotted or tabulated and a summary of the results is given in Section II.

A. 2N1671B

Figures 9-13 are plots of the average values of device parameters verus electron fluence where Fig. 9 shows interbase resistance; Fig. 10 valley voltage; Fig. 11 peak point voltage; Fig. 11 peak point voltage; Fig. 12 emitter saturation voltage; and Fig. 13 intrinsic stand-off ratio. In addition, Table 10 shows interbase modulated current and Table 18 emitter reverse current and peak point emitter current before and after exposure.

B. 2N3980

Figures 14-18 are plots of the average values of device parameters versus electron fluence where Fig. 14 shows interbase resistance; Fig. 15 valley voltage; Fig. 16 peak point voltage; Fig. 17 emitter saturation voltage; and Fig. 18 intrinsic stand-off ratio. Table 19 shows interbase modulated current and Table 17 emitter reverse current and peak point emitter current before and after exposure.

C. 2N3484

Figures 19-23 are plots of the average values of device parameters versus electron fluence where Fig. 19 shows interbase resistance; Fig. 20 valley voltage; Fig. 21 peak point voltage; Fig. 22 emitter saturation voltage; and Fig. 23 intrinsic stand-off ratio. Table 19 has tabulated interbase modulated current and Table 18 emitter reverse current and peak point emitter current before and after exposure.

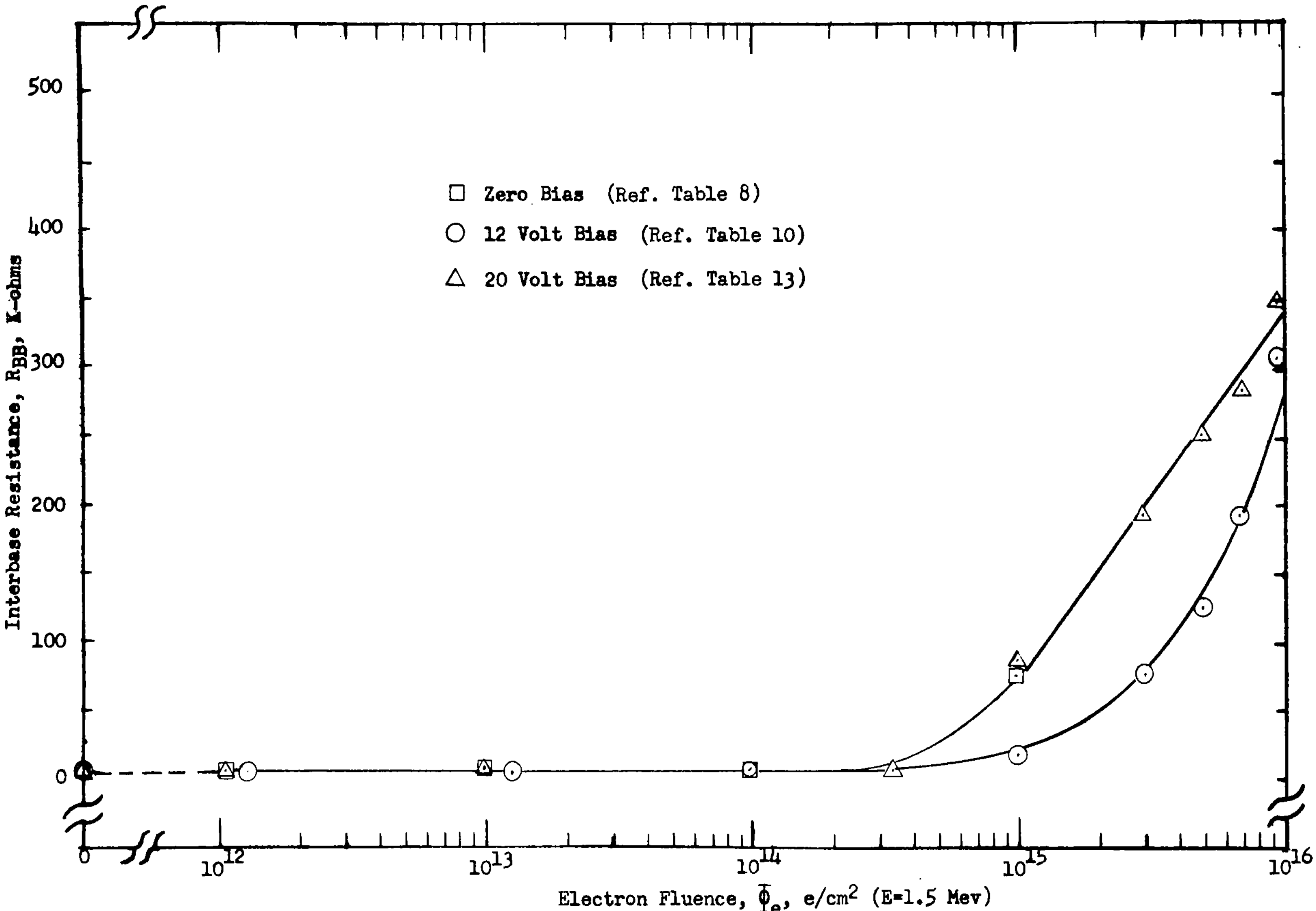


Figure 9. Interbase Resistance (R_{BB}) versus Electron Fluence for 2N1671B.

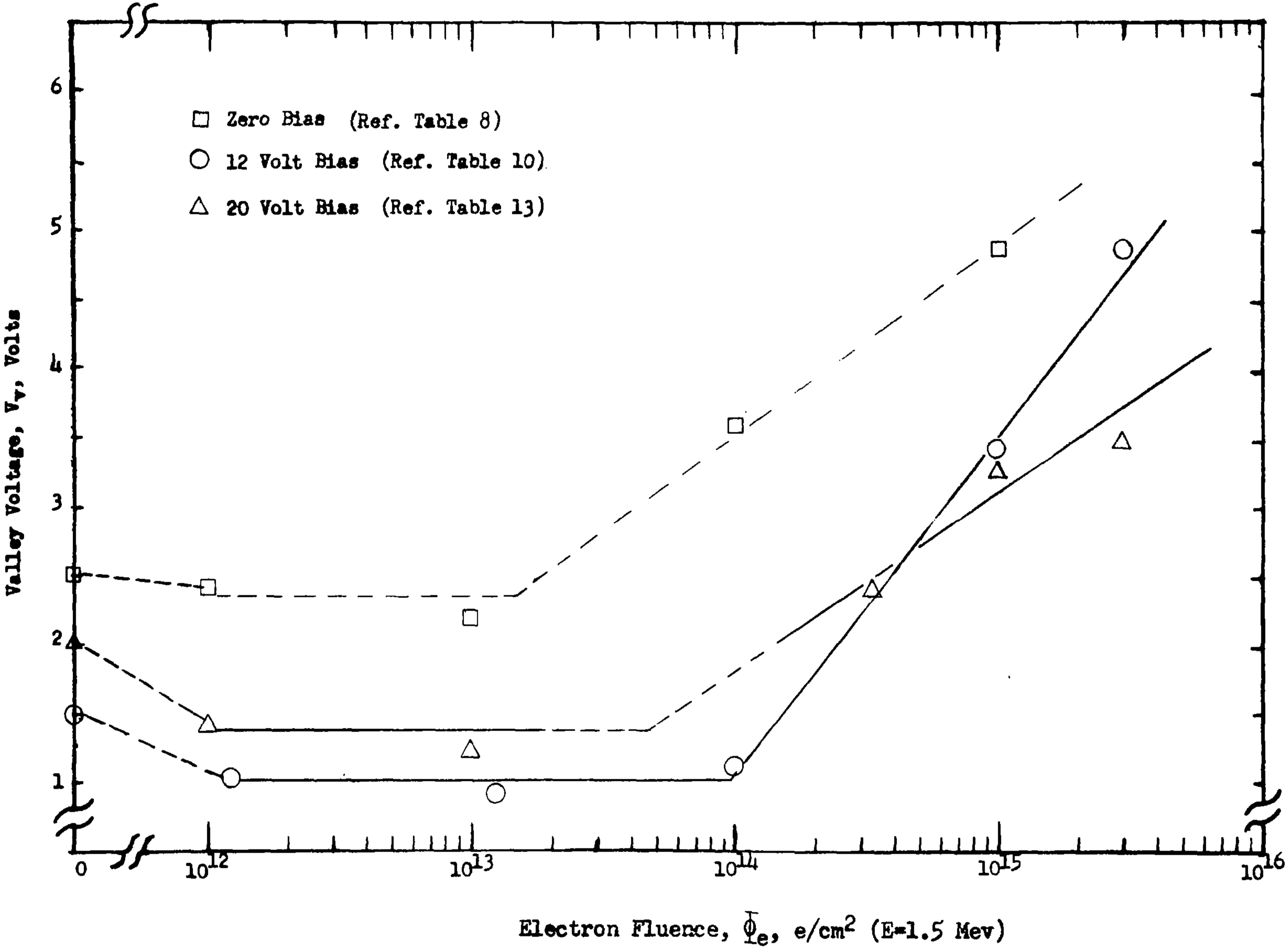


Figure 10. Valley Voltage (V_v) versus Electron Fluence for 2N1671B.

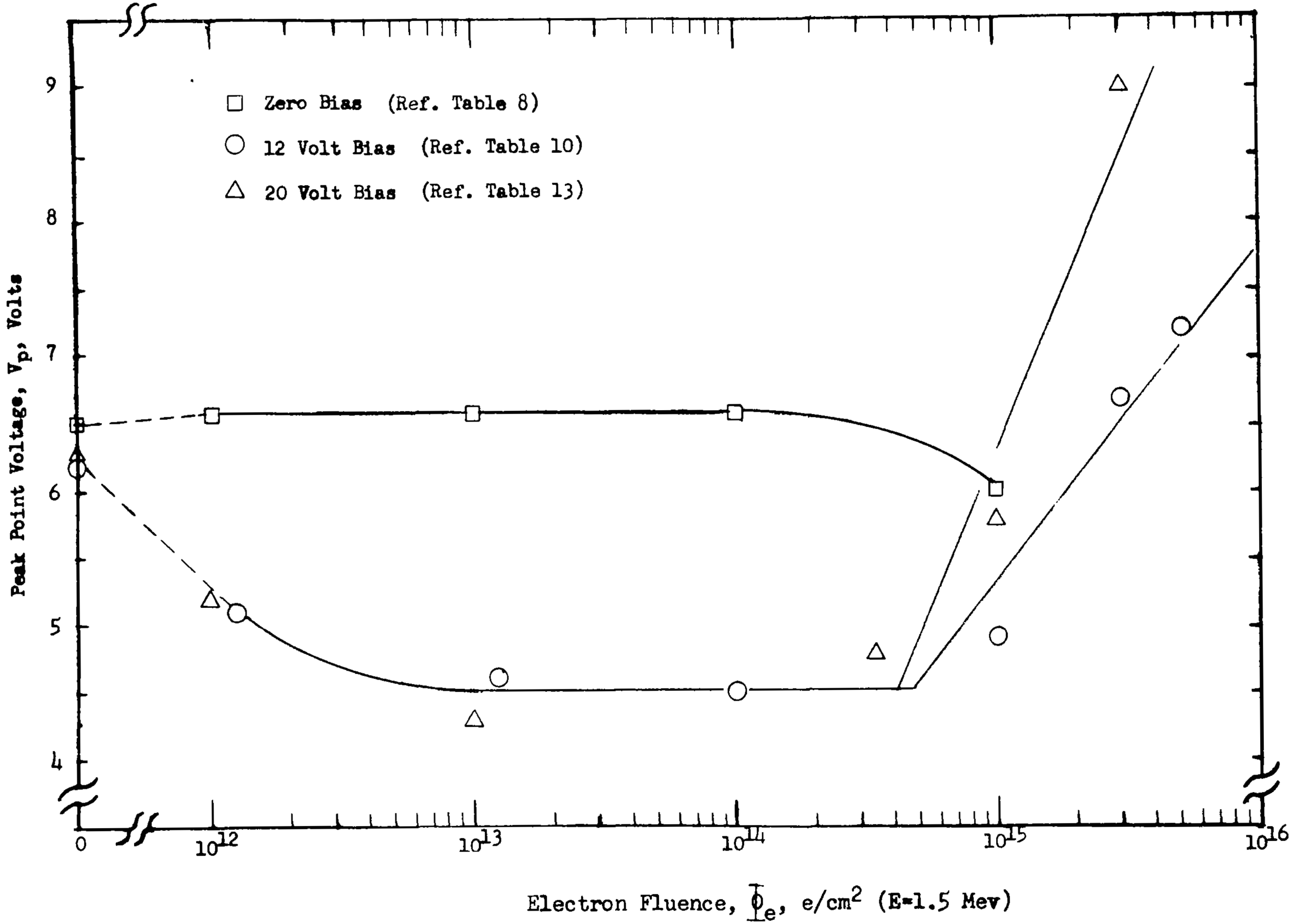


Figure 11. Peak Point Voltage (V_p) versus Electron Fluence for 2N1671B.

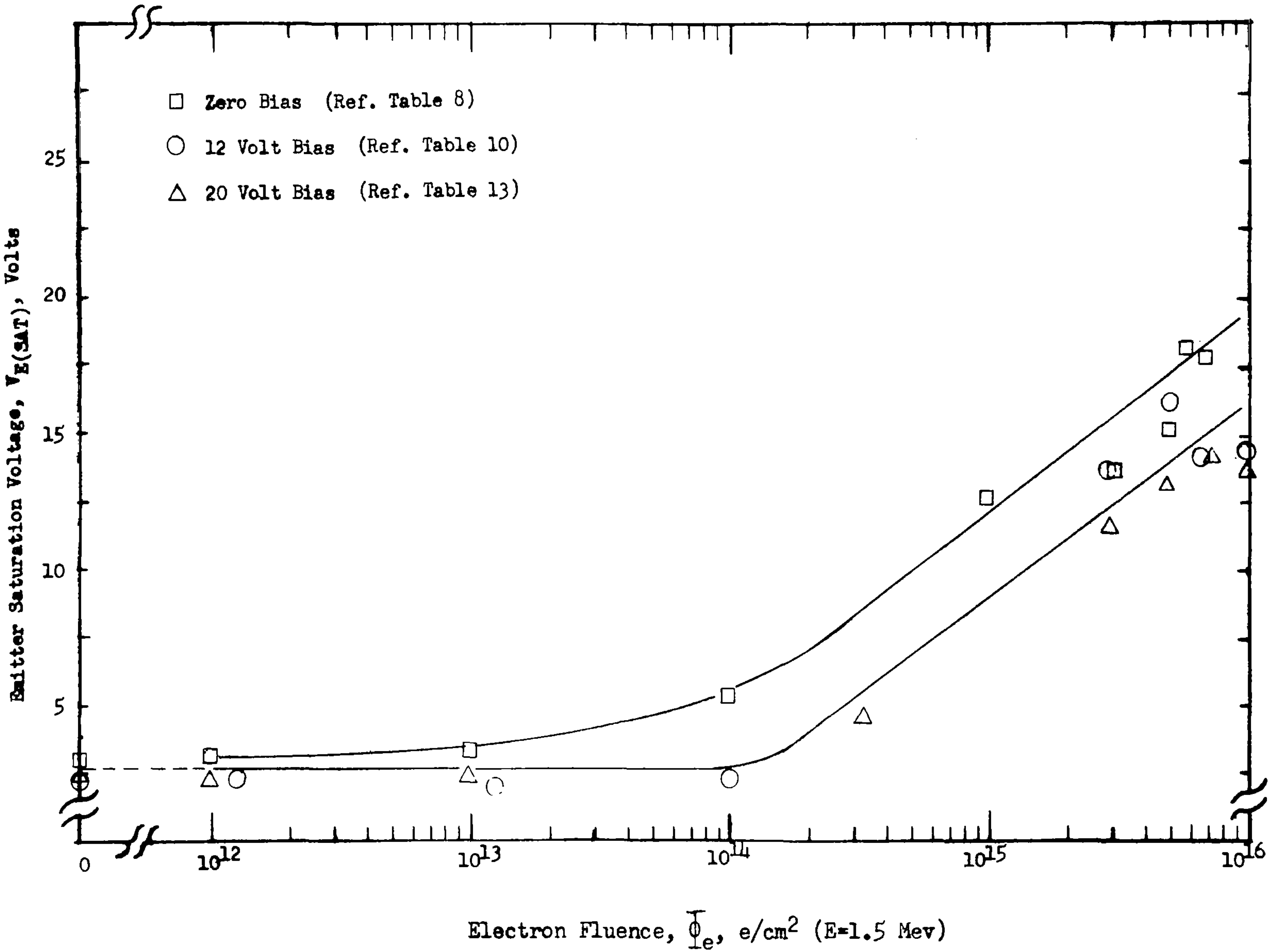


Figure 12. Emitter Saturation Voltage ($V_{E(SAT)}$) versus Electron Fluence for 2N1671B.

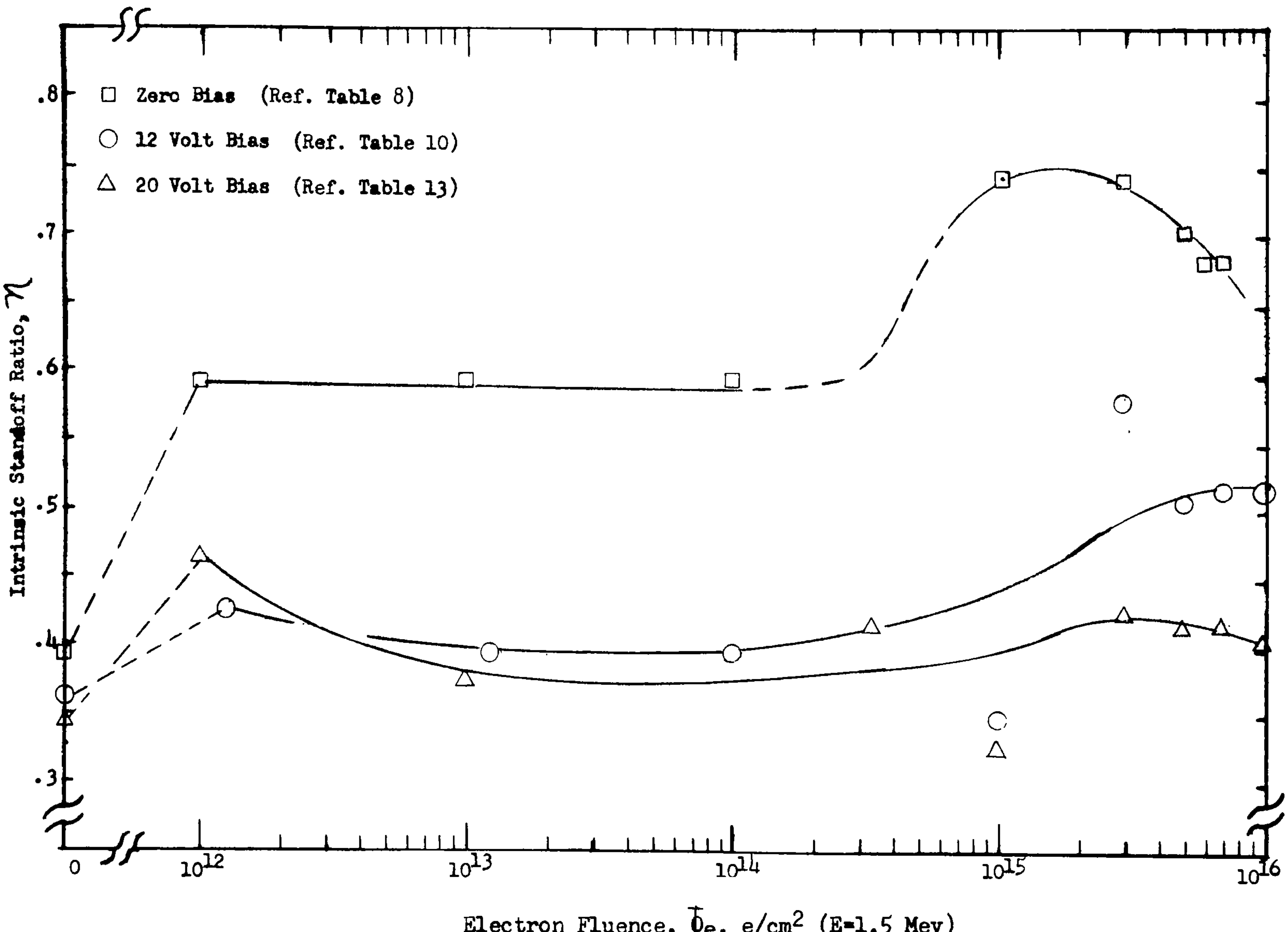


Figure 13. Intrinsic Standoff Ratio (η) versus Electron Fluence for 2N1671B.

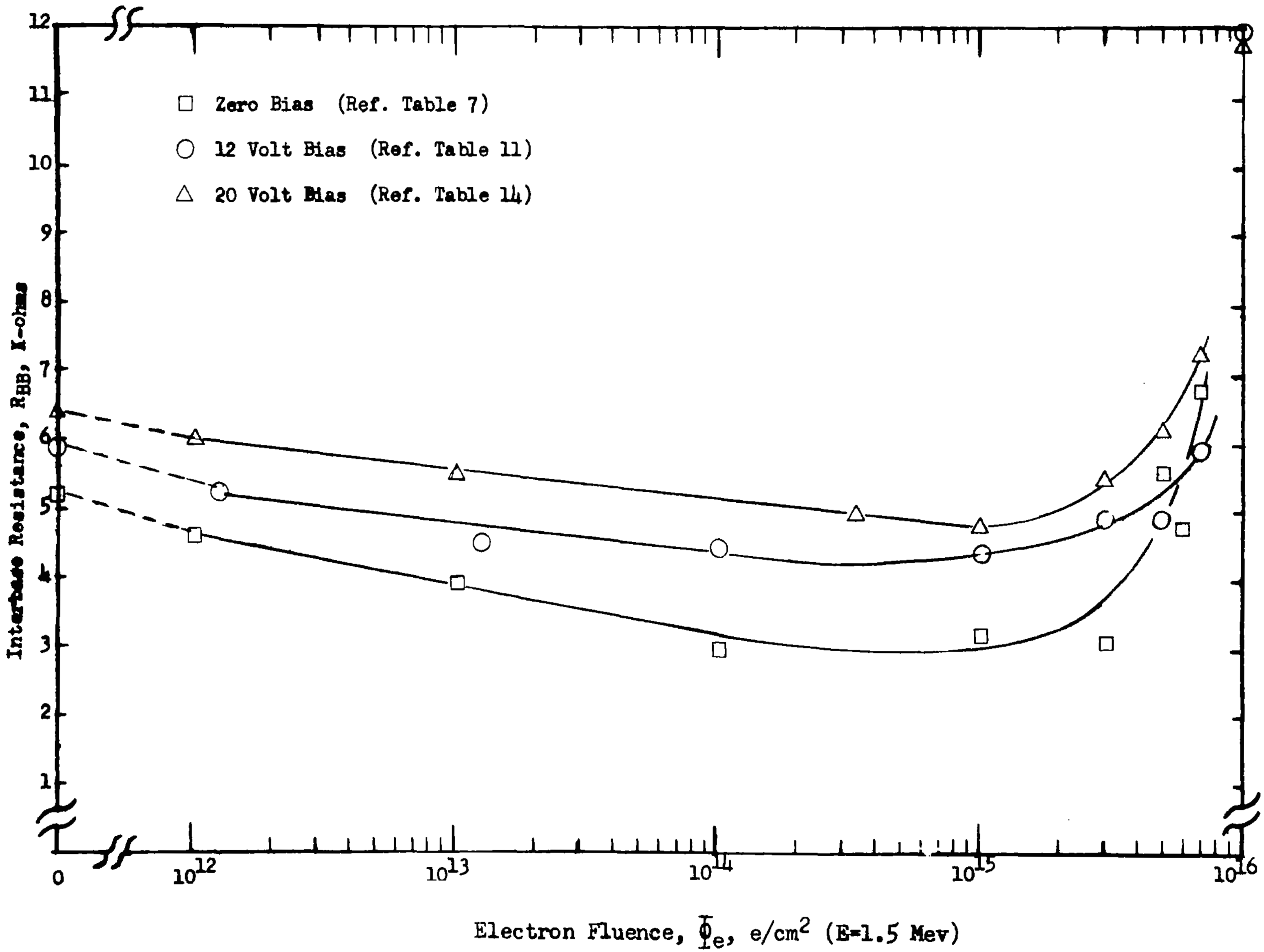


Figure 14. Interbase Resistance (R_{BB}) versus Electron Fluence for 2N3980.

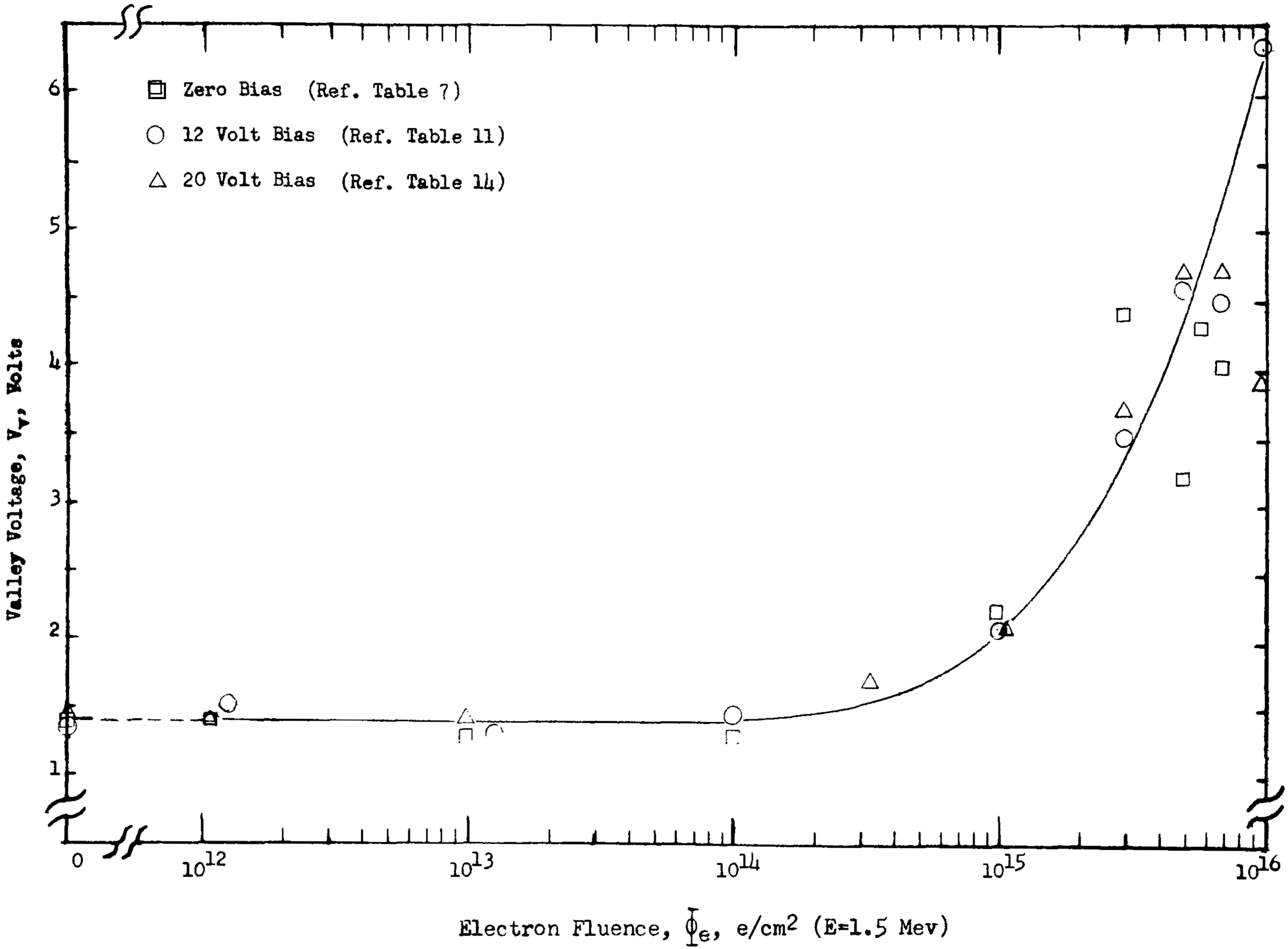


Figure 15. Valley Voltage (V_v) versus Electron Fluence for 2N3980.

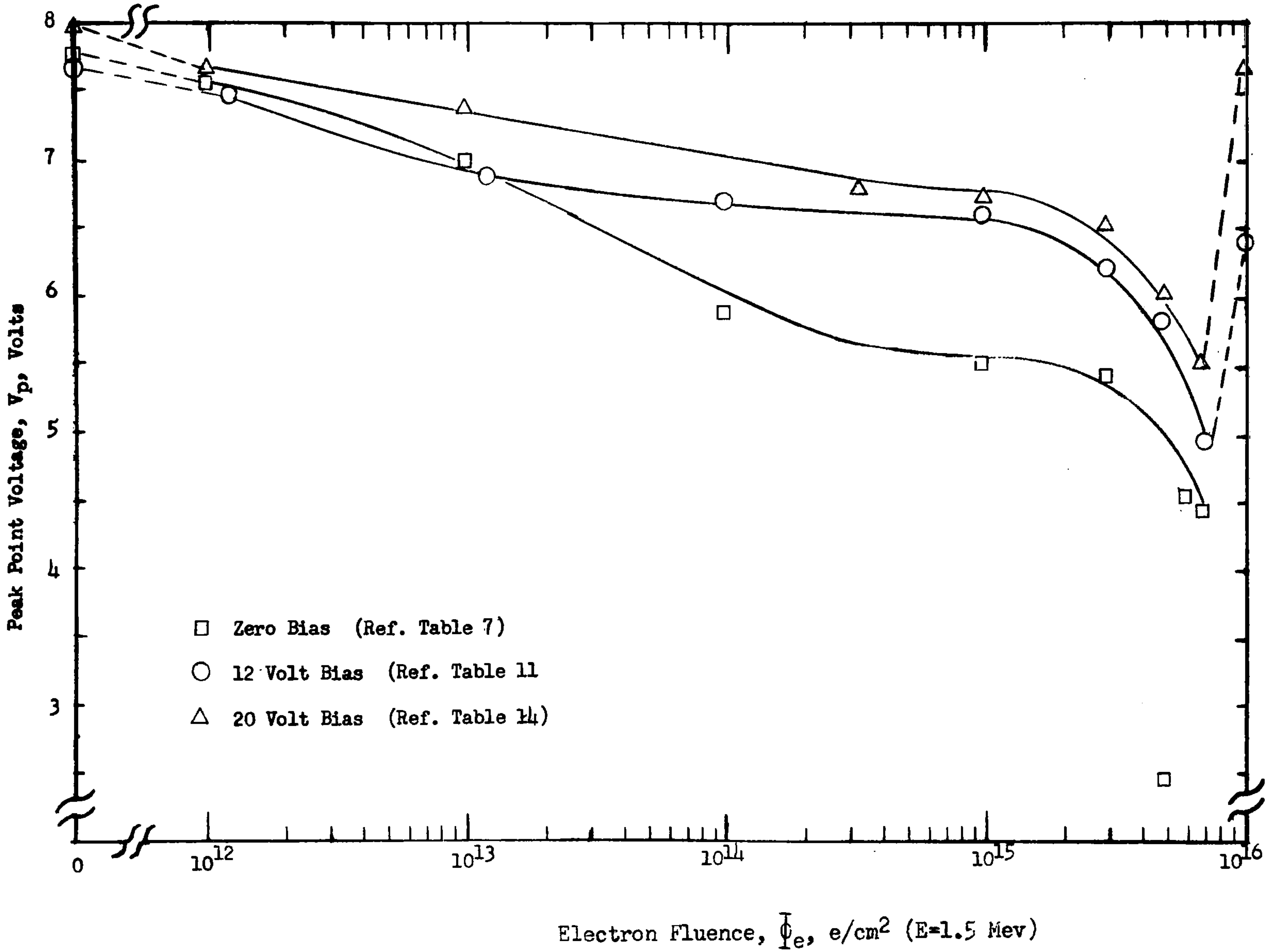


Figure 16. Peak Point Voltage (V_p) versus Electron Fluence for 2N3980.

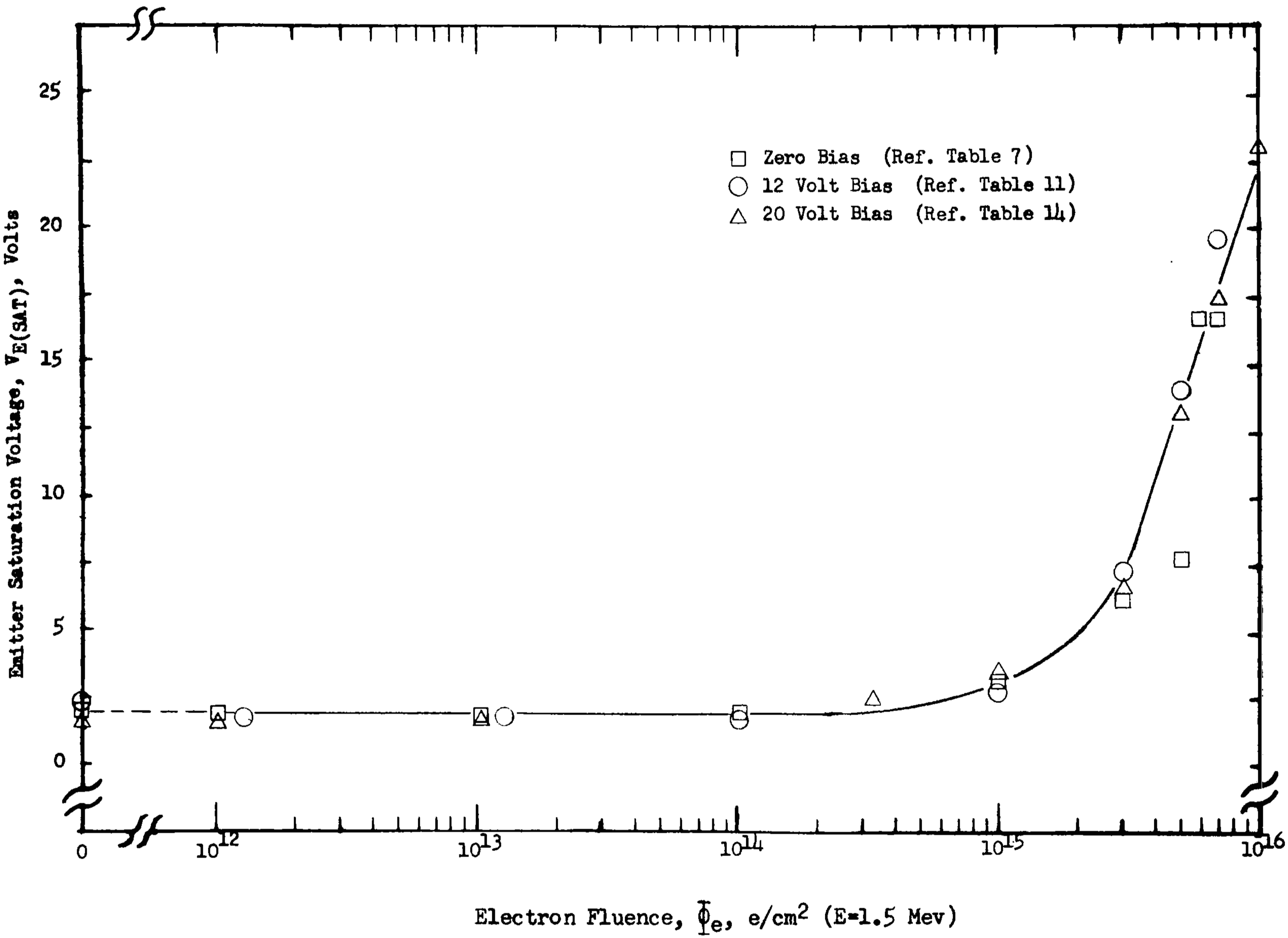


Figure 17. Emitter Saturation Voltage ($V_{E(SAT)}$) versus Electron Fluence for 2N3980.

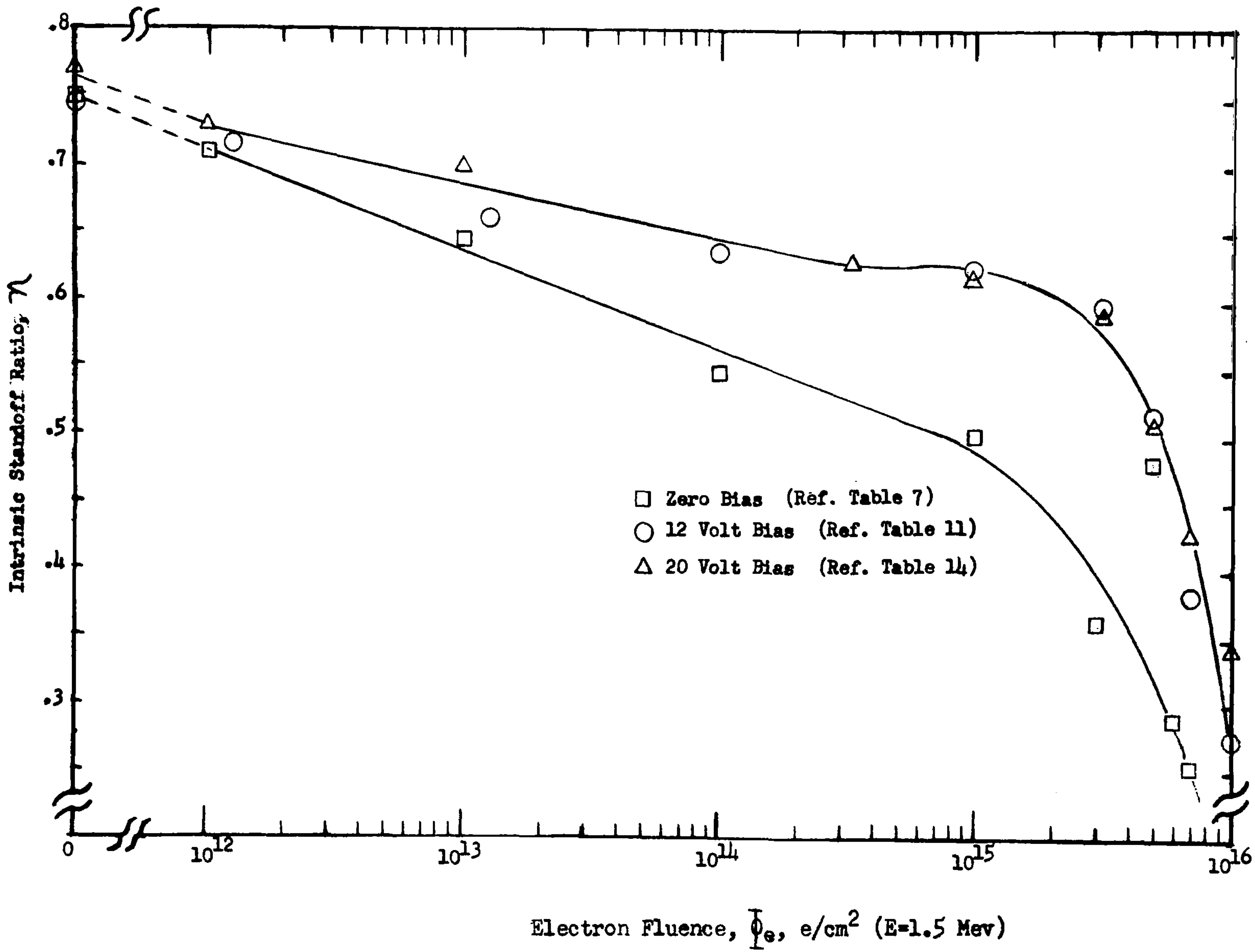


Figure 18. Intrinsic Standoff Ratio (η) versus Electron Fluence for 2N3980.

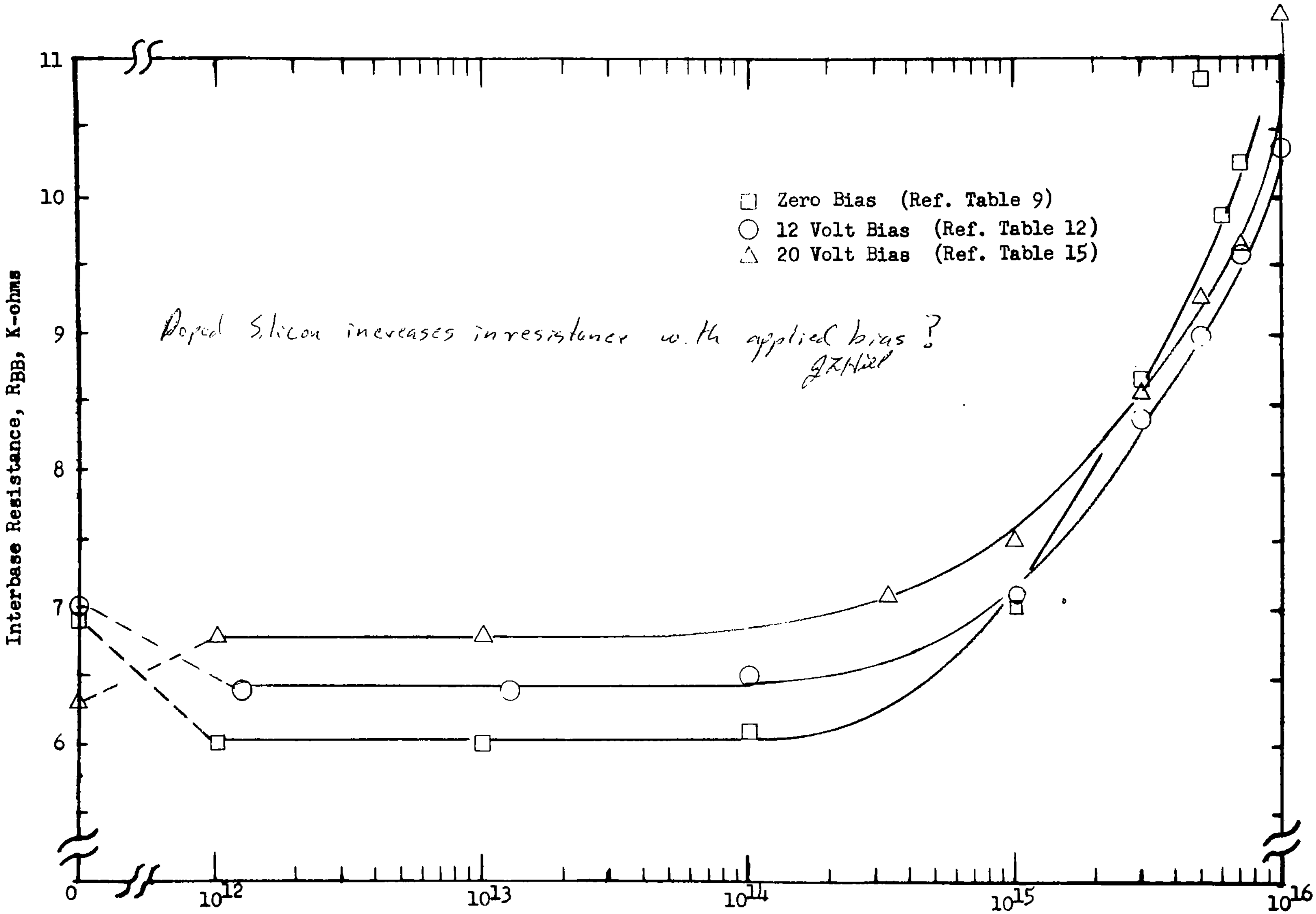


Figure 19. Interbase Resistance (R_{BB}) versus Electron Fluence for 2N3484.

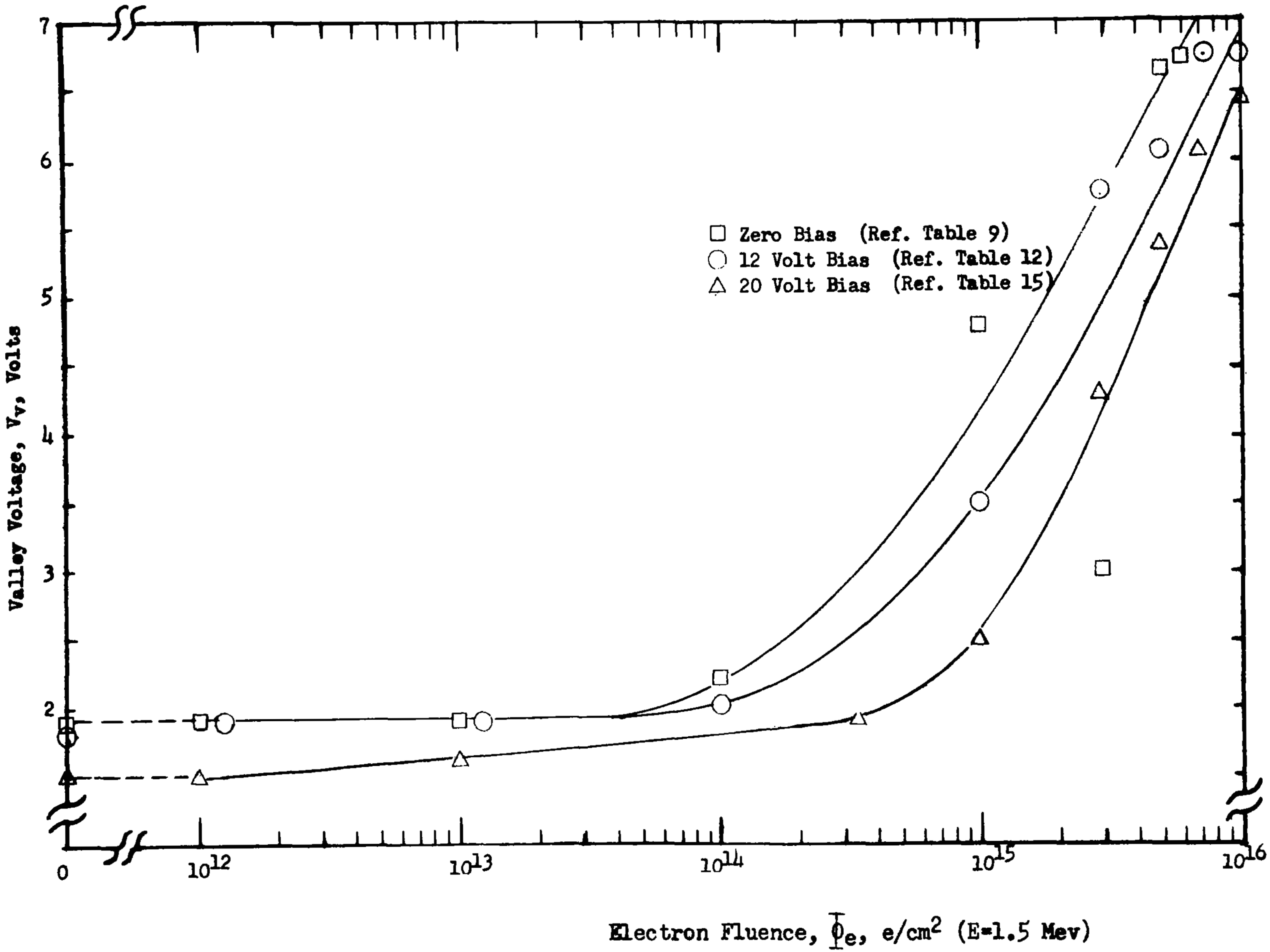


Figure 20. Valley Voltage (V_v) versus Electron Fluence for 2N3484.

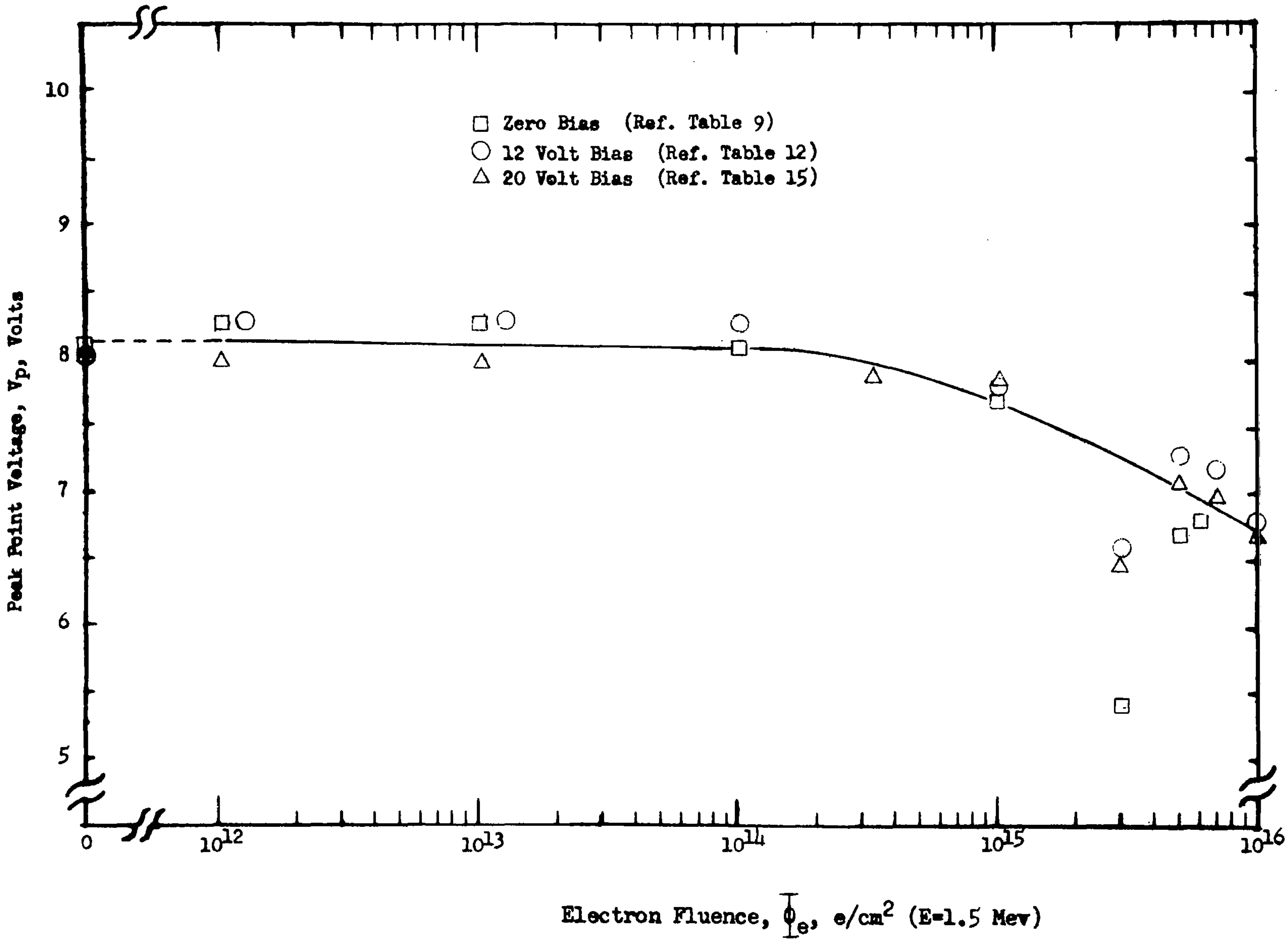


Figure 21. Peak Point Voltage (V_p) versus Electron Fluence for 2N3484.

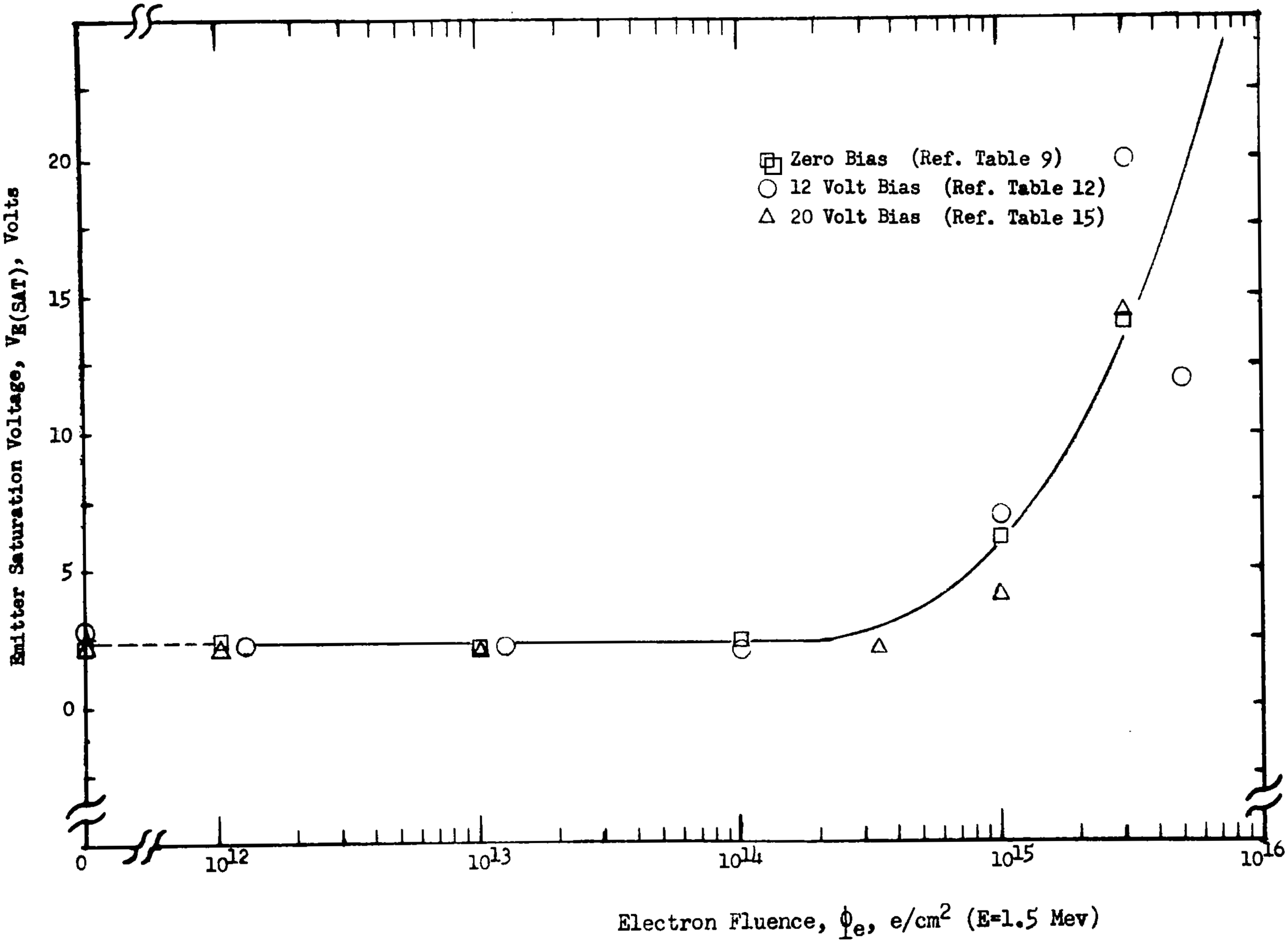


Figure 22. Emitter Saturation Voltage ($V_{E(SAT)}$) versus Electron Fluence for 2N3484.

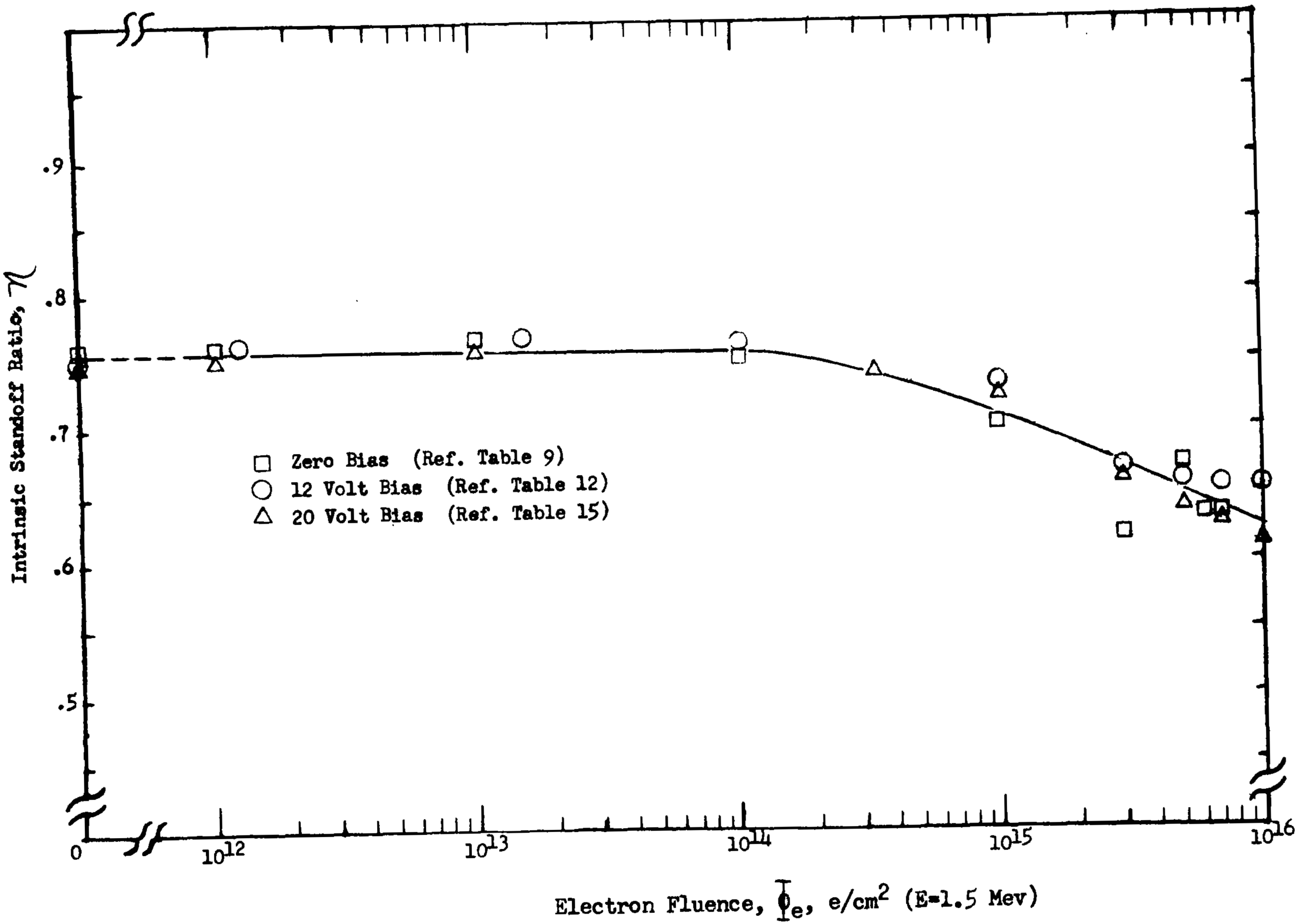


Figure 23. Intrinsic Standoff Ratio (η) versus Electron Fluence for 2N3484.

NASA-Langley, 1966 CR-526

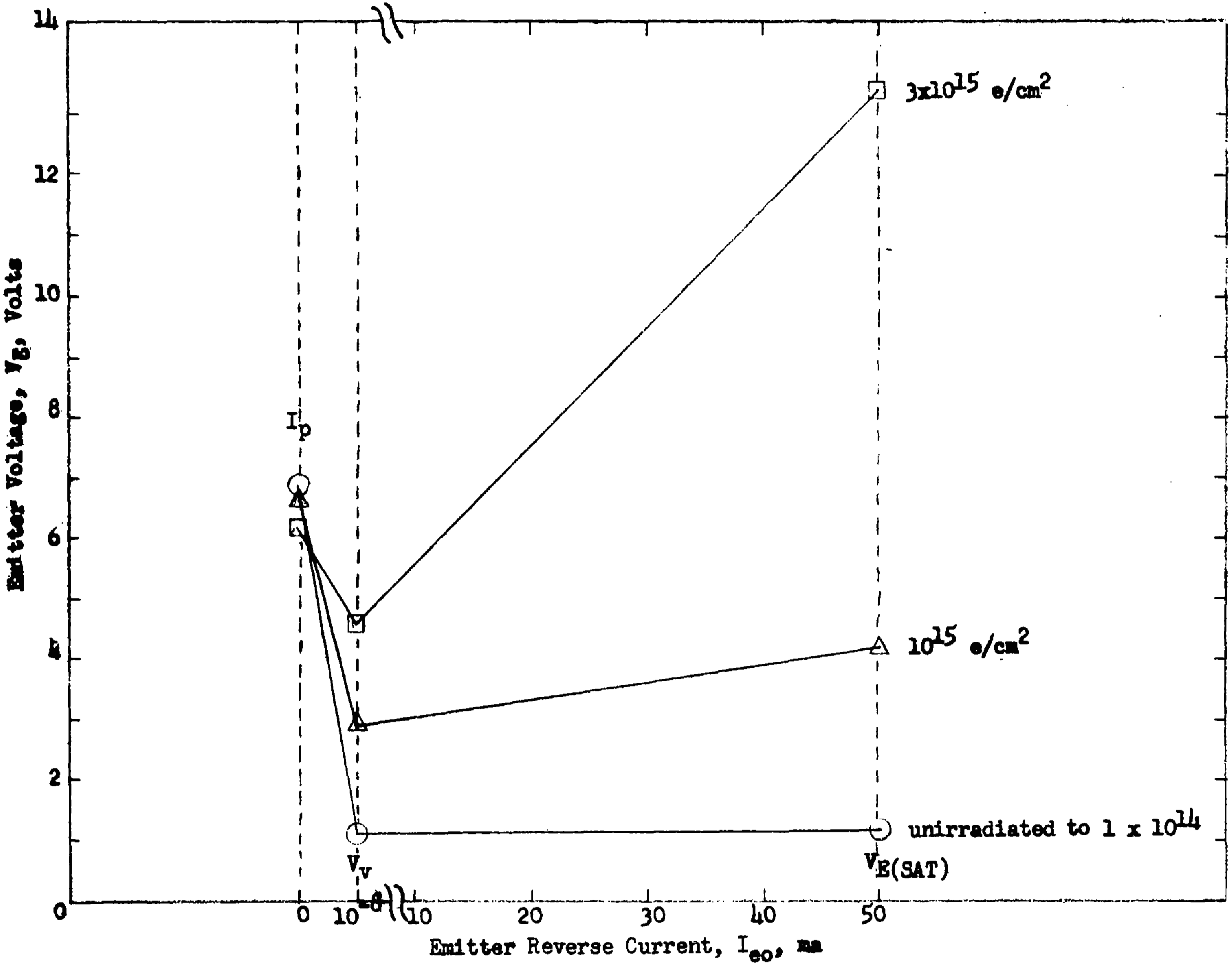


Figure 24. Emitter Current versus Emitter Voltage for 2N3484 #6 at Zero Volt Bias.