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May 1979

DEVELOPMENT OF A PYROLYTIC GRAPHITE GRID VERSION OF THE 4CW100,000E

Varian EIMAC Division

Sterling G. McNees

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The purpose of this project was to evaluate pyrolytic graphite grids. Several tubes were built to the same general geometry as the 4CW100,000E. The X2097U has a pyrolytic grid and screen. The number of grid bars was increased by 50% to improve cutoff characteristics. The stem was redesigned to improve thermal cycling stability. The X2097V in addition had a high density filament which increased perveance by 30%. The tubes are physically interchangeable with the 4CW100,000E and in critical applications requiring high grid and screen dissipation and low drive voltage have superior performance.

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EVALUATION

This report gives a brief description of an attempt to fabricate Pyrolytic Graphite control and screen grids for a standard EIMAC 4CW100,000E tetrode tube. Some results of the program are presented along with recommendation for future work. Typically a tetrode is limited in total capability by the limited power handling ability of the grids. Grid current interception tends to produce secondary electrons which limit control of the total tube current. Also the power dissipated in the grid causes primary electron emission from the grid if the temperature is excessive. Thus this program attempts to correct some of these problems by using higher allowable temperature limits of pyrolytic graphite and its lower tendency to emit secondary electrons.

BOBBY GRAY
Project Engineer

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PYROLYTIC GRAPHITE DESCRIPTION

The purpose of this Contract was to build several power grid tubes as nearly like the 4CW100,000E as possible, but with pyrolytic grids, and in another version have a double density filament.

Pyrolytic graphite is an interesting form of carbon. It has high hot strength and dimensional stability along with a very low coefficient of thermal expansion. Its low secondary emission coefficient coupled with a relatively high work function all make for a good grid material. Even the high electrical resistance (20 times moly) is not all bad as this will tend to prevent parasitic oscillations. Because of pyrolytic high emissivity of .77, this increase in resistance for the same grid drive will cause only a moderate increase in grid operating temperature when compared with the 4CW100,000E. In Table I the pertinent material characteristics are given along with a comparison of moly and copper. Pyrolytic graphite is manufactured from natural gas using a CVD process.* It is not an invariant material and its characteristics are critically dependent on the manufacturing process and controls.

TABLE I

	Pyrolytic Graphite		Molybdenum	Copper
	A B Plane	C Plane		
Density gm/cm^3	2.21		10.2	8.89
Tensile Strength kg/m^2	$13 \cdot 10^6$	$317 \cdot 10^3$	$100 \cdot 10^6$	$15 \cdot 10^6$
Thermal Conductivity $W/cm^2/^oC/cm$ 20^oC	3.98	.018	1.6	3.94
1000^oC	1.88	.011	1.1	3.6
Specific Heat $joules/cm^3/^oC$	2.41		2.66	3.42
Total Thermal Expansion 20^o-1000^oC	.24%	1.6%	.6%	2.1%
Total Emissivity 1000^oC	.77	.5	.25	.04
Electrical Resistivity ohm cm 20^oC	$4.3 \cdot 10^{-4}$	.67	$8 \cdot 10^{-6}$	$1.8 \cdot 10^{-6}$
1000^oC	$1.6 \cdot 10^{-4}$		$2.9 \cdot 10^{-5}$	$8.6 \cdot 10^{-6}$

*For further reading see "Pyrolytic Graphite". William H. Smith & Donald Leeds, Modern Materials, Vol. 7 1970 Academic Press.

Tube Design

The layout of the X2097U and V is shown in Figure 1. The only difference between the two tube types is the density of the filament. All copper parts which were used in the stem of the 4CW100,000E were replaced with molybdenum and Kovar. The internal brazes were replaced with heliarc welds. These changes improved the internal maximum safe operating temperature as well as improving dimensional accuracy. The increased current required for the double density filament presented no problem with this new stem design.

In a power grid tube using a non-focussing geometry the electrical performance is improved by reducing grid bar diameter and increasing the number of bars. Pyrolytic graphite strength is such that increasing the number of grid bars to 120 from 80, used in the 4CW100,000E, was practical and did not hurt tube rigidity.

Tube Testing

As part of the tube evaluation various tube characteristics were measured and these results are given in the tube curves in the Appendix. For comparison purposes refer to Figures X, Y, Z, ZZ.

Test Results

Characteristic Curves.

Test results were consistent with prediction. When compared with the 4CW100,000E the X2097U shows a signigicant improvement in perveance. Perveance is mostly a function of grid filament spacing and this increase was due mostly to the closer hot spacing caused by the low expansion of pyrolytic graphite. The X2097V has even higher perveance and this is caused by the increased filament wire area. Although the area is double the perveance increase was only 30%.

The increase in grid bars to 120 had a significant effect on reducing grid cutoff voltage. This reduces grid drive voltage but if the tube is driven positive the high grid current characteristic of pyrolytic graphite will prevent a reduction in grid drive power.

The high grid dissipation capabilities of pyrolytic graphite are best utilized by increasing the screen operating voltage which in a typical application will reduce the grid current. Because of low secondary emission grid current in both the X2097U and X2097V is quite high. For rf application the X2097V with 2000V screen looks like an interesting choice of operating parameters. Since melting or changing of surface texture are not a problem with pyrolytic graphite; the limiting factor for grid dissipation is the

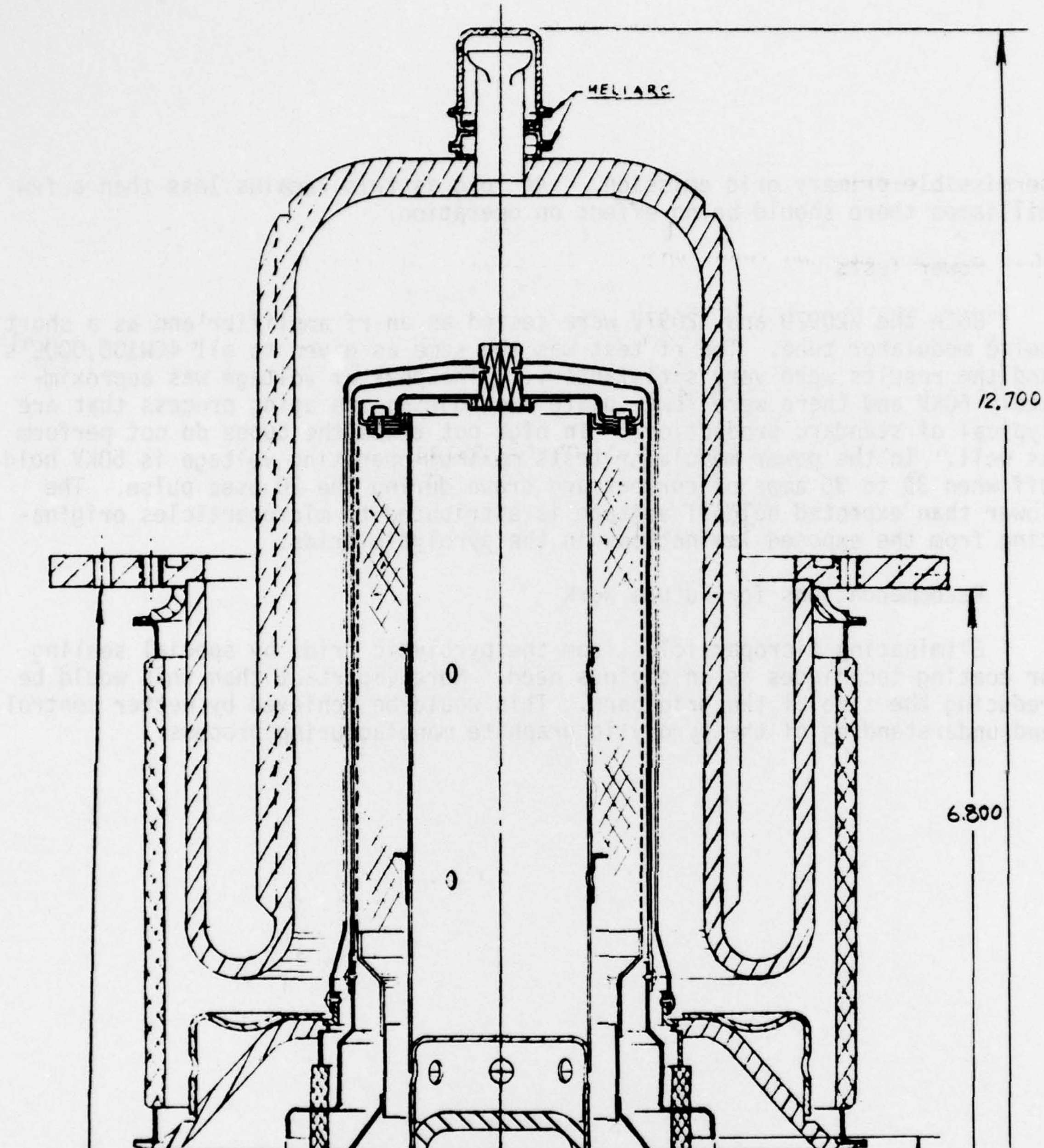


FIGURE 1. LAYOUT DRAWING OF X2097U and X2097V

permissible primary grid emission. As long as this remains less than a few milliamps there should be no effect on operation.

Power Tests

Both the X2097U and X2097V were tested as an rf amplifier and as a short pulse modulator tube. The rf test was the same as given to all 4CW100,000E's and the results were very satisfactory. The peak rf voltage was approximately 60KV and there were fewer plate arcs during the aging process that are typical of standard production. In high pot tests the tubes do not perform as well. In the power modulator tests maximum operating voltage is 50KV holdoff when 30 to 35 amps of current are drawn during the 20 usec pulse. The lower than expected holdoff voltage is attributed to microparticles originating from the exposed laminations in the pyrolytic grids.

Recommendations for Future Work

Eliminating microparticles from the pyrolytic grids by special sealing or coating techniques is an obvious need. More important than this would be reducing the size of the grid bars. This would be achieved by better control and understanding of the pyrolytic graphite manufacturing process.

APPENDIX

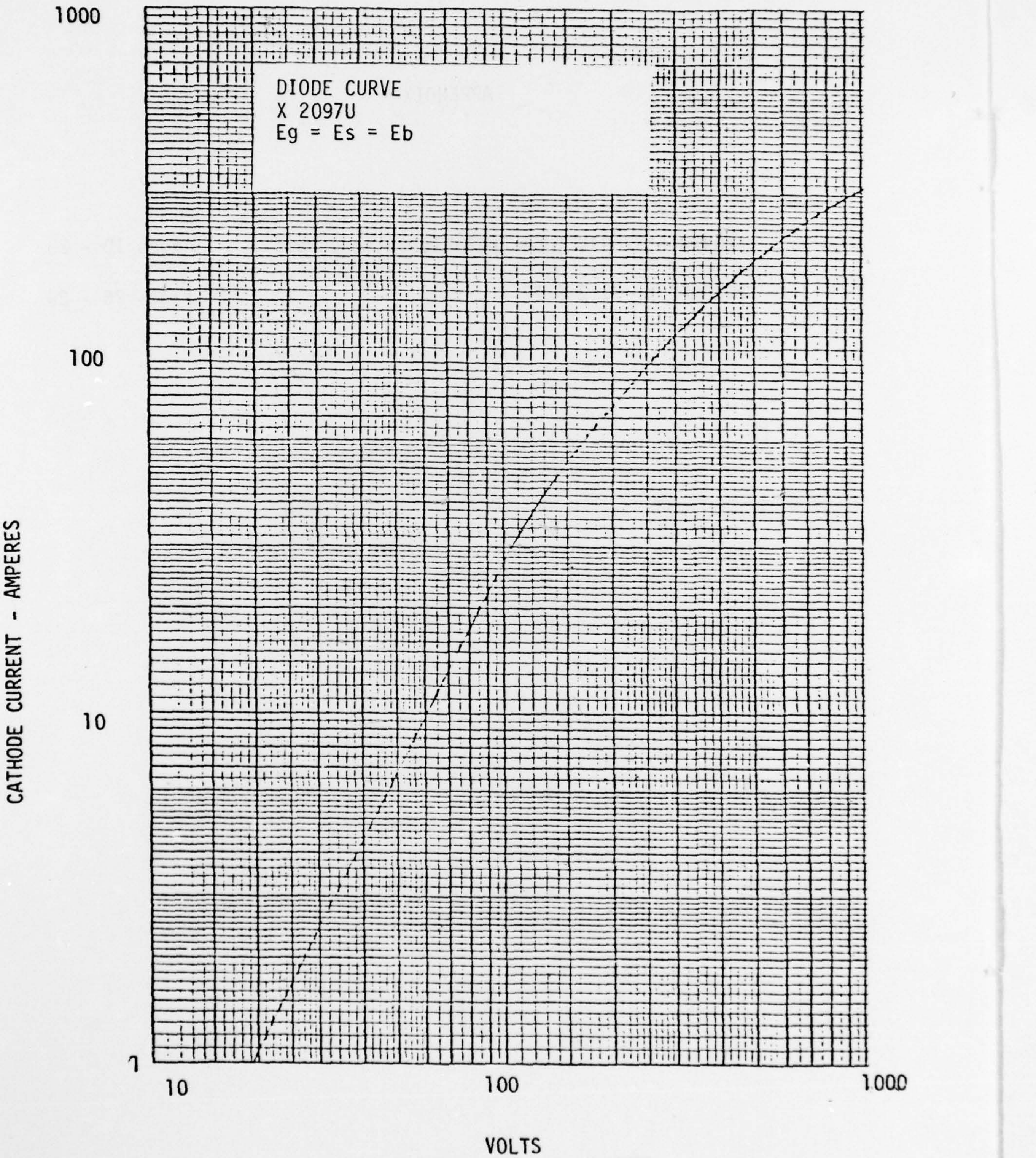


Fig A1. Diode Curve - X2097U

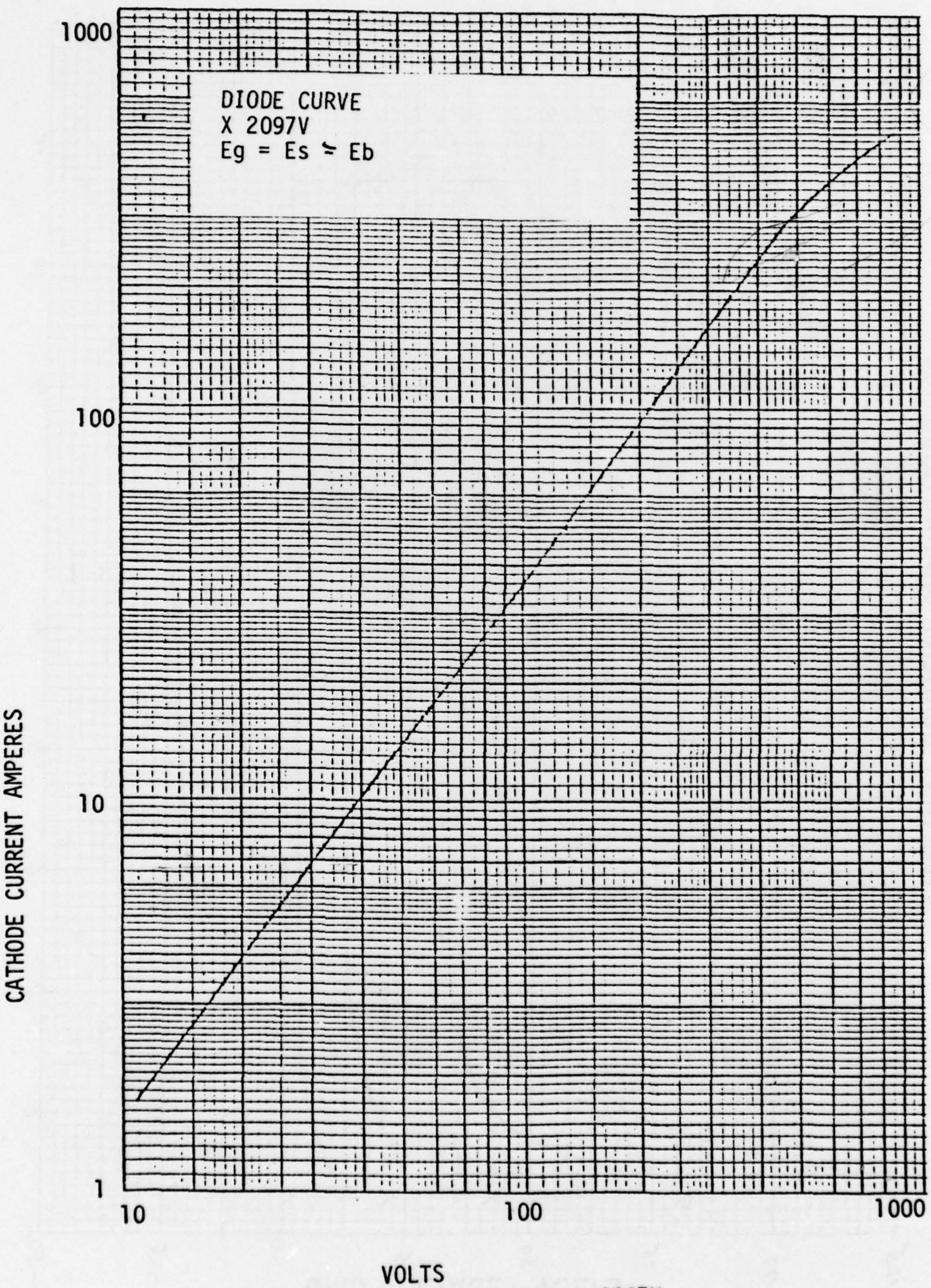


Fig. A2 - Diode Curve - X-2097V

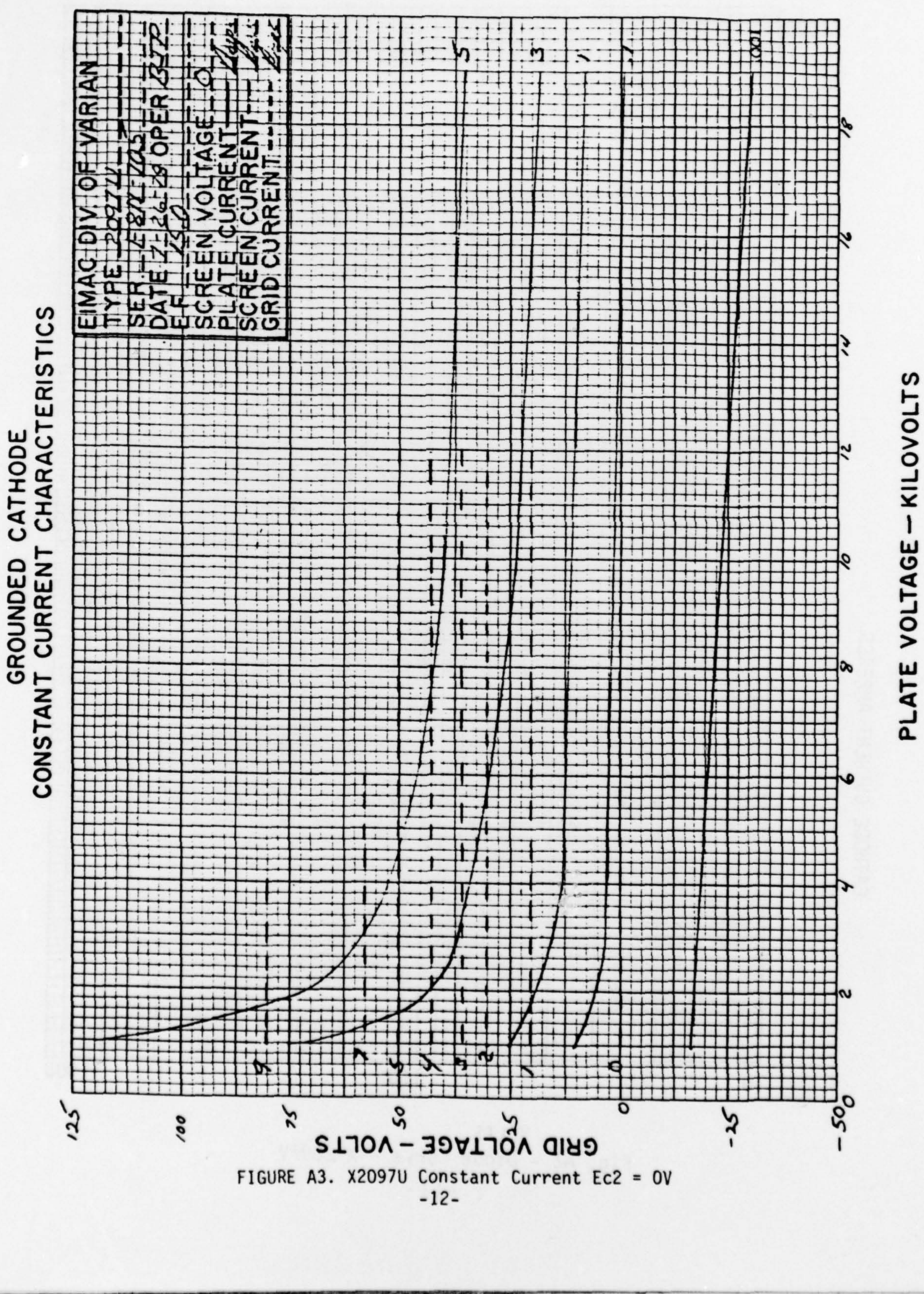


FIGURE A3. X2097U Constant Current Ec2 = 0V

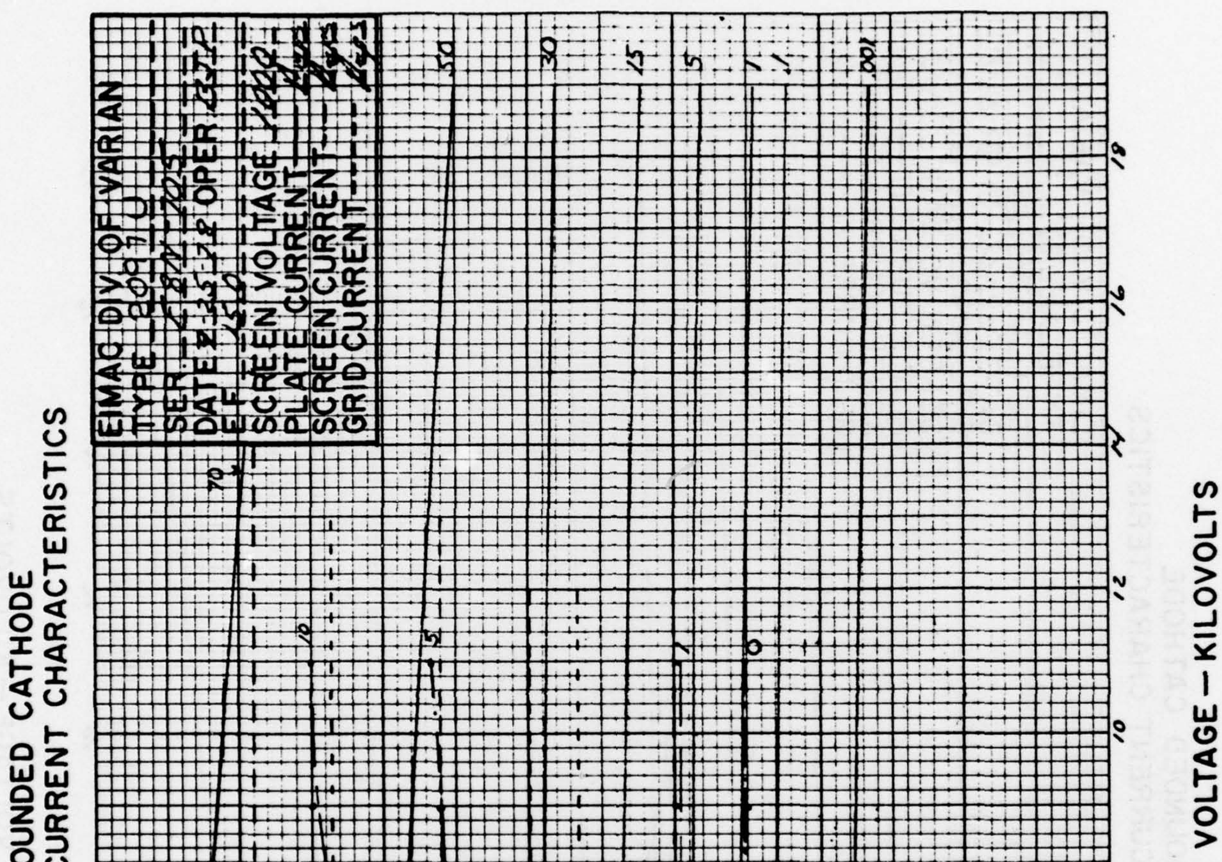


FIGURE A4. X2097U Constant Current Ec2 = 1000V

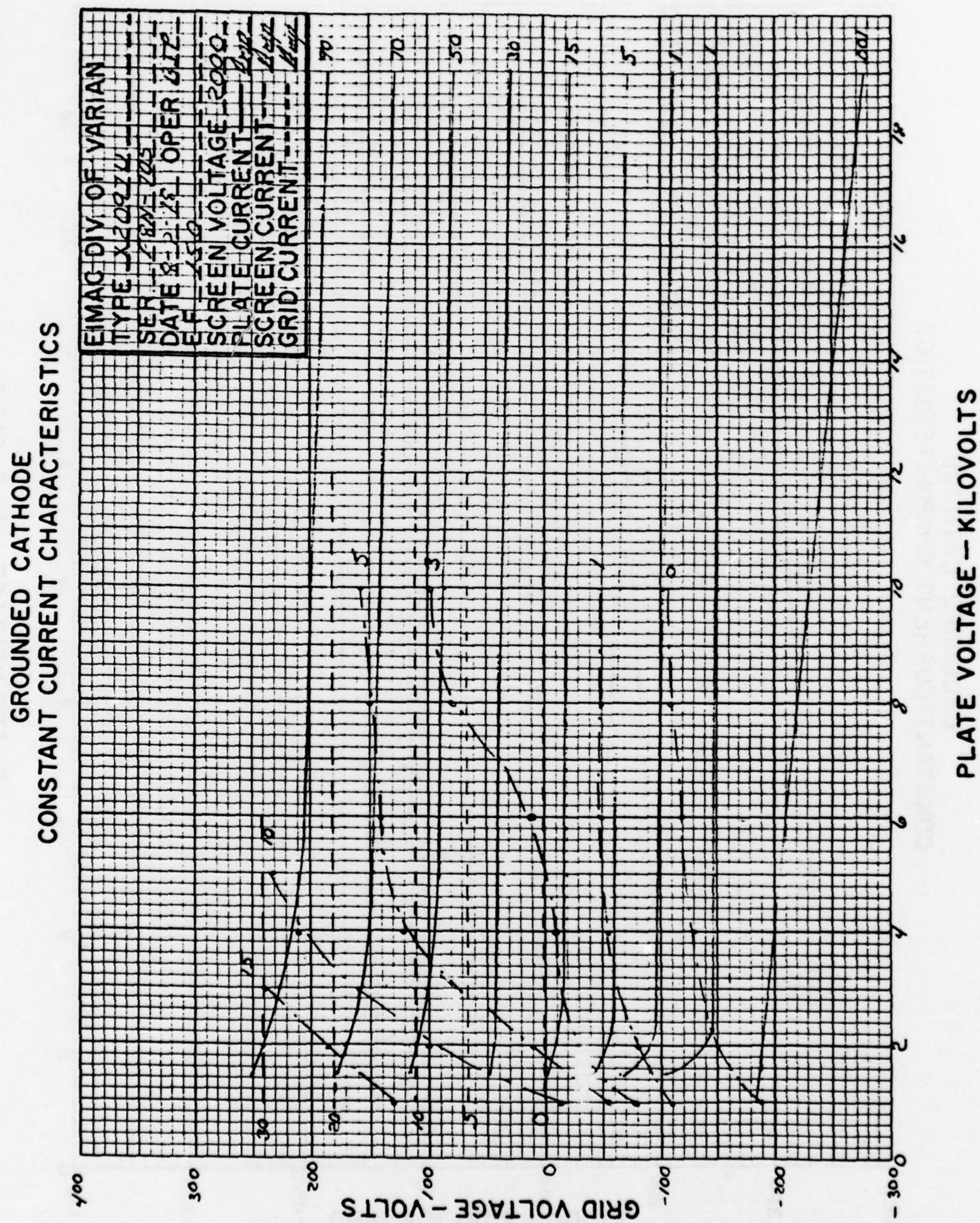


FIGURE A5. X2097U Constant Current Ec2 = 2000V

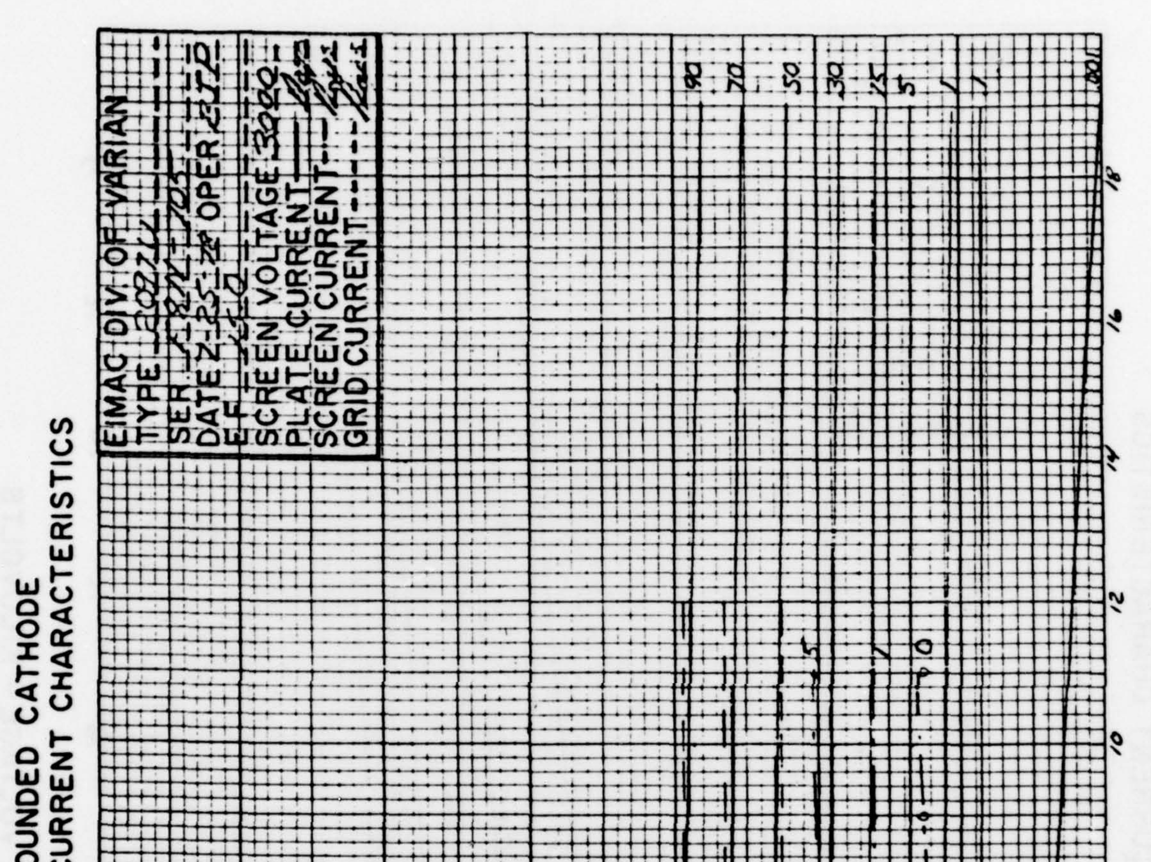


FIGURE A6. X2097U Constant Current Ec2 = 3000V

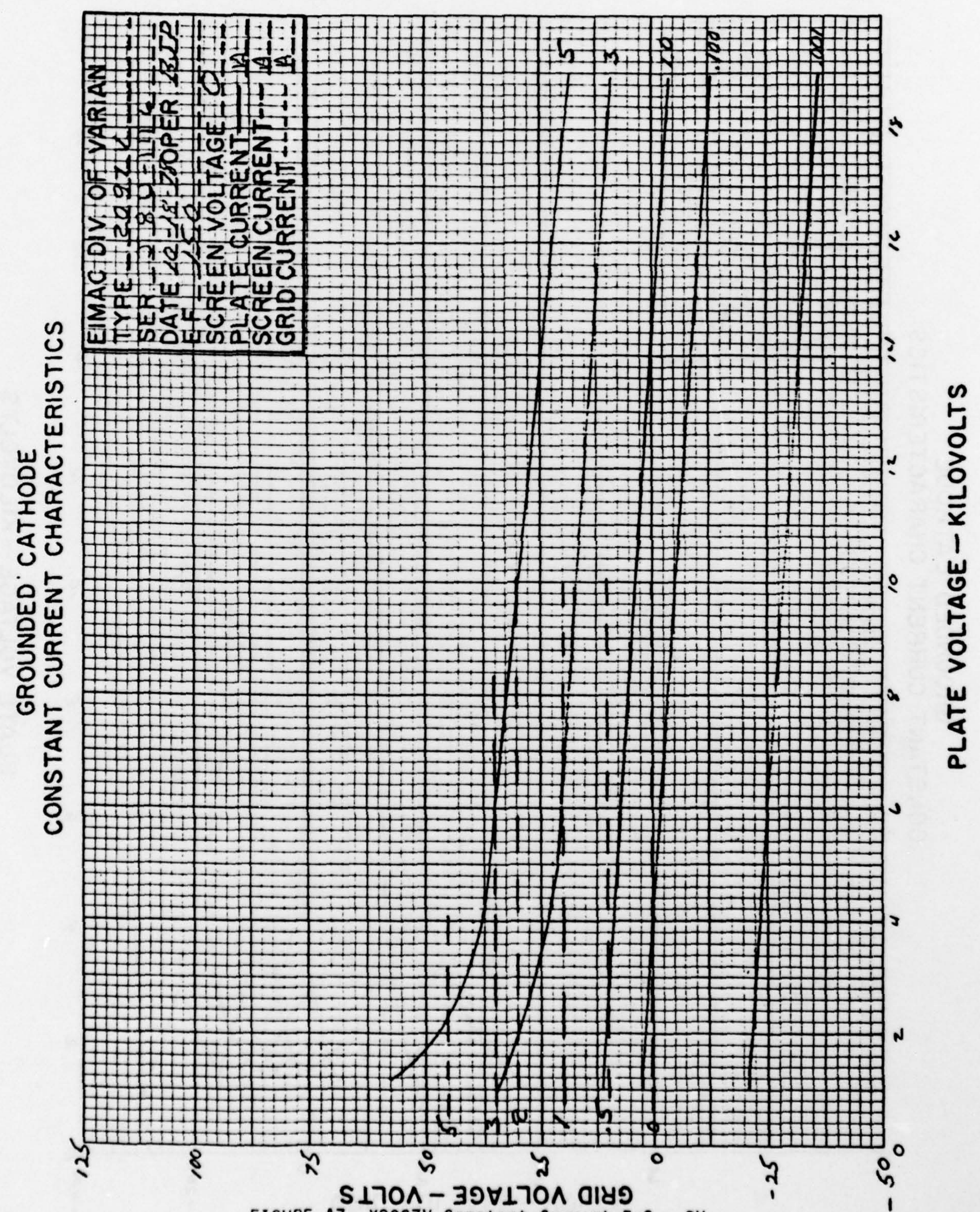


FIGURE A7. X2097V Constant Current Ec2 = 0V

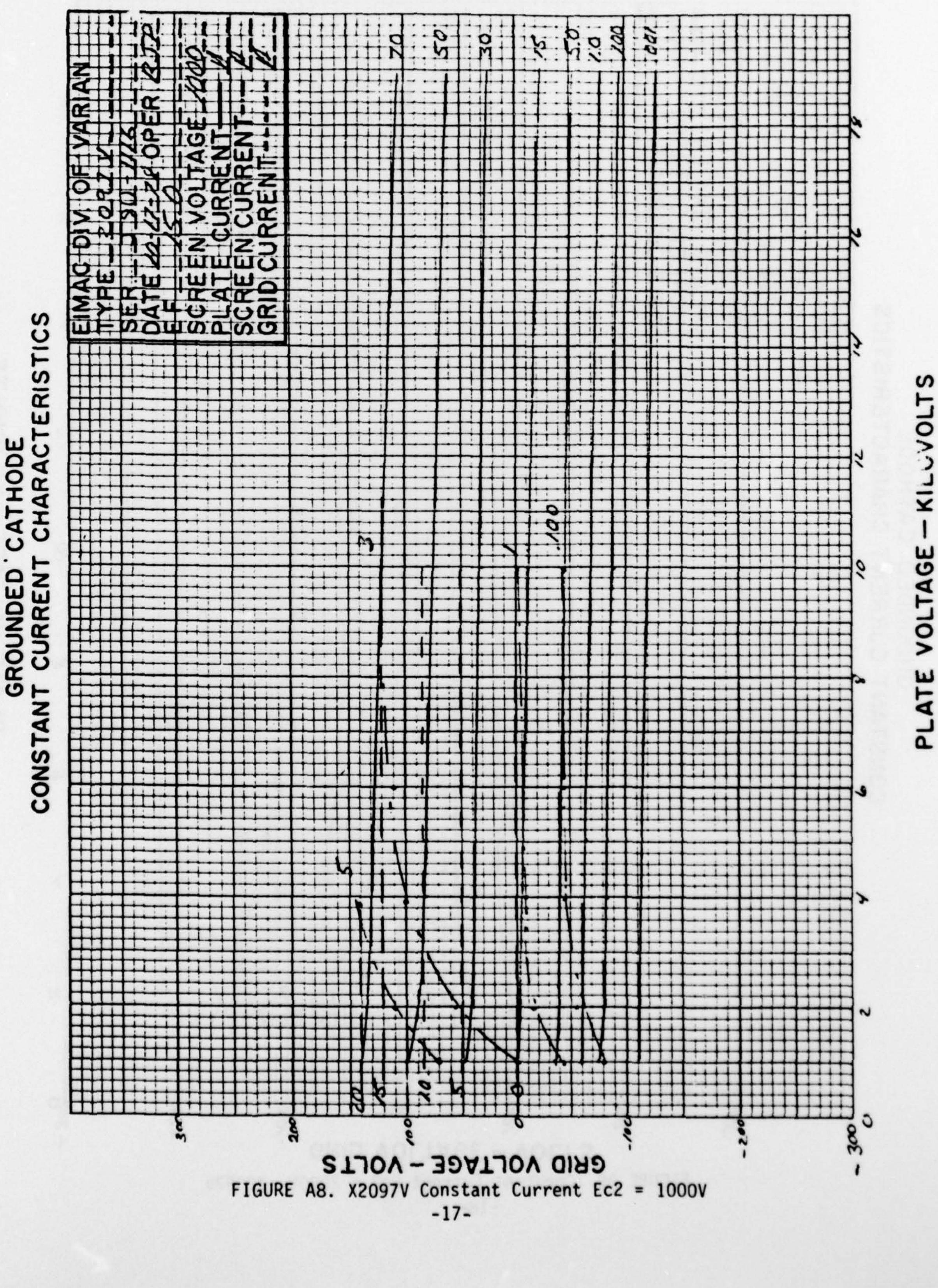


FIGURE A8. X2097V Constant Current Ec2 = 1000V

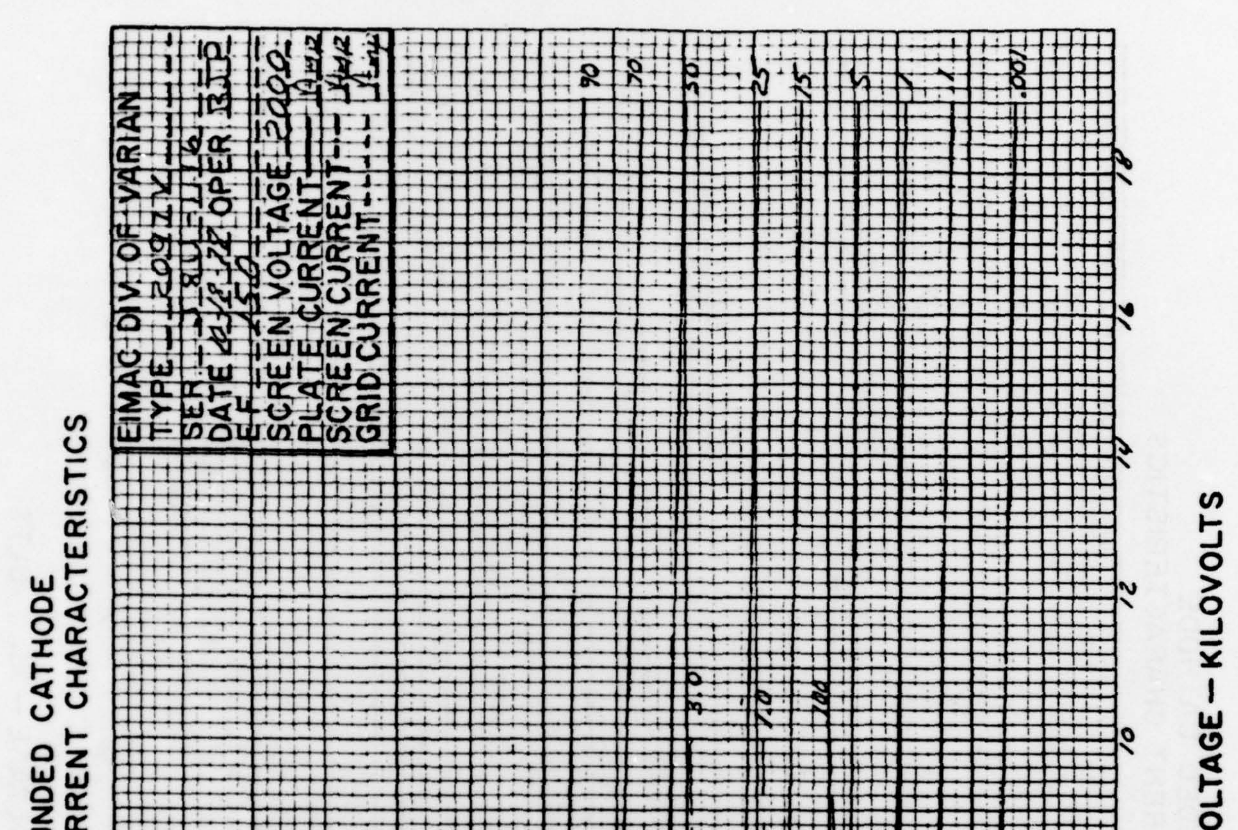


FIGURE A9. Constant Current Ec2 = 2000V X2097V

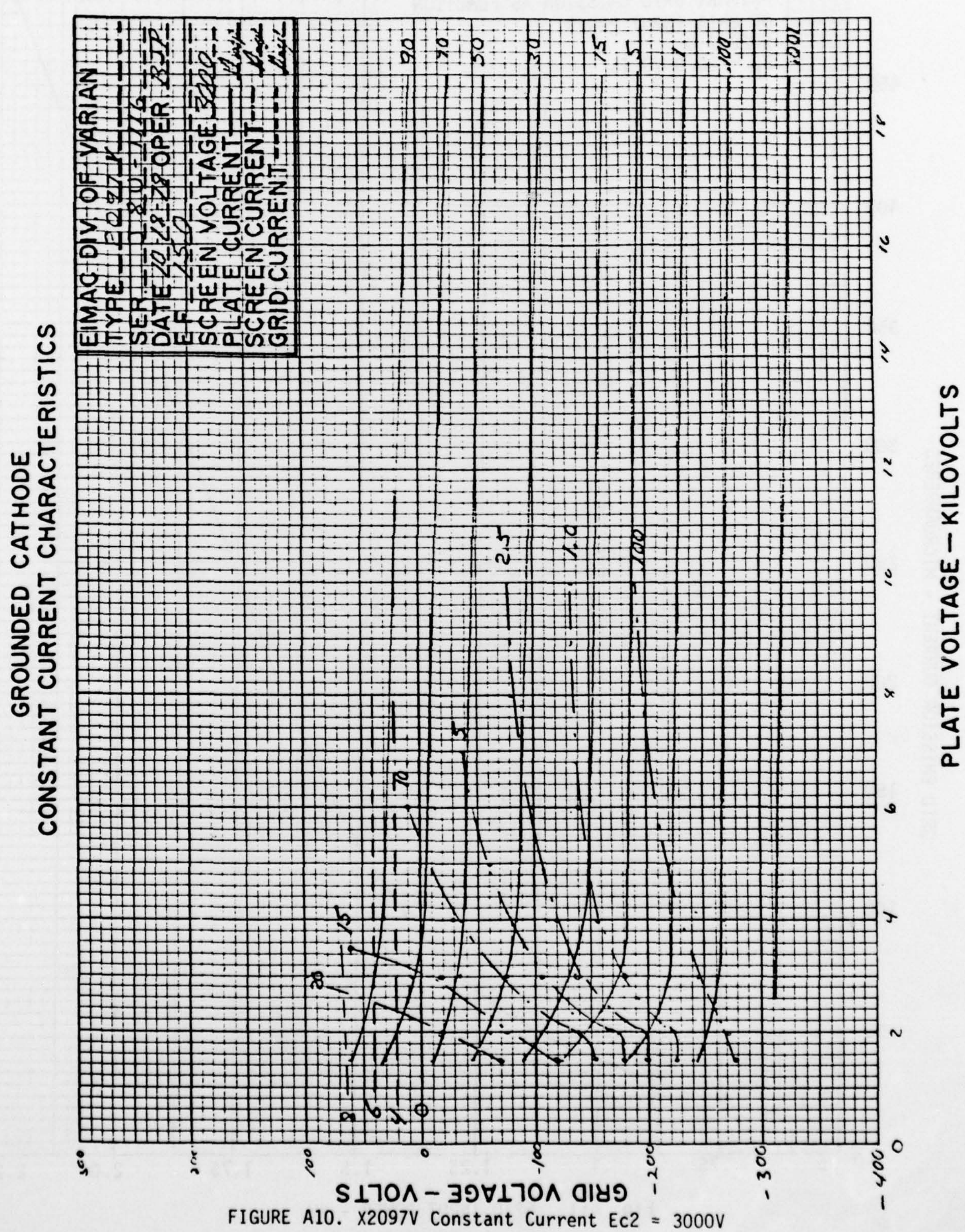


FIGURE A10. X2097V Constant Current Ec2 = 3000V

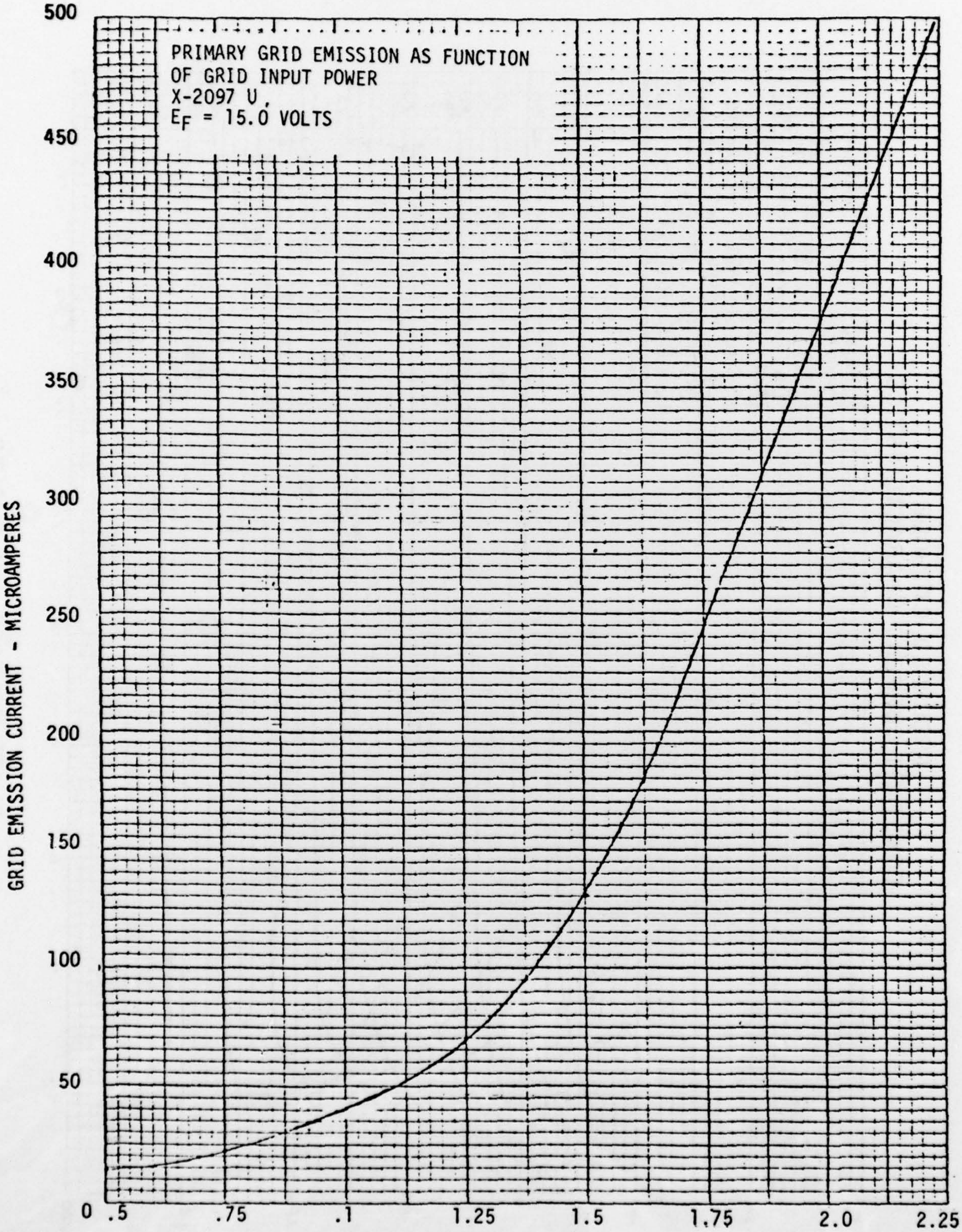


Fig. A11. GRID INPUT POWER - KW

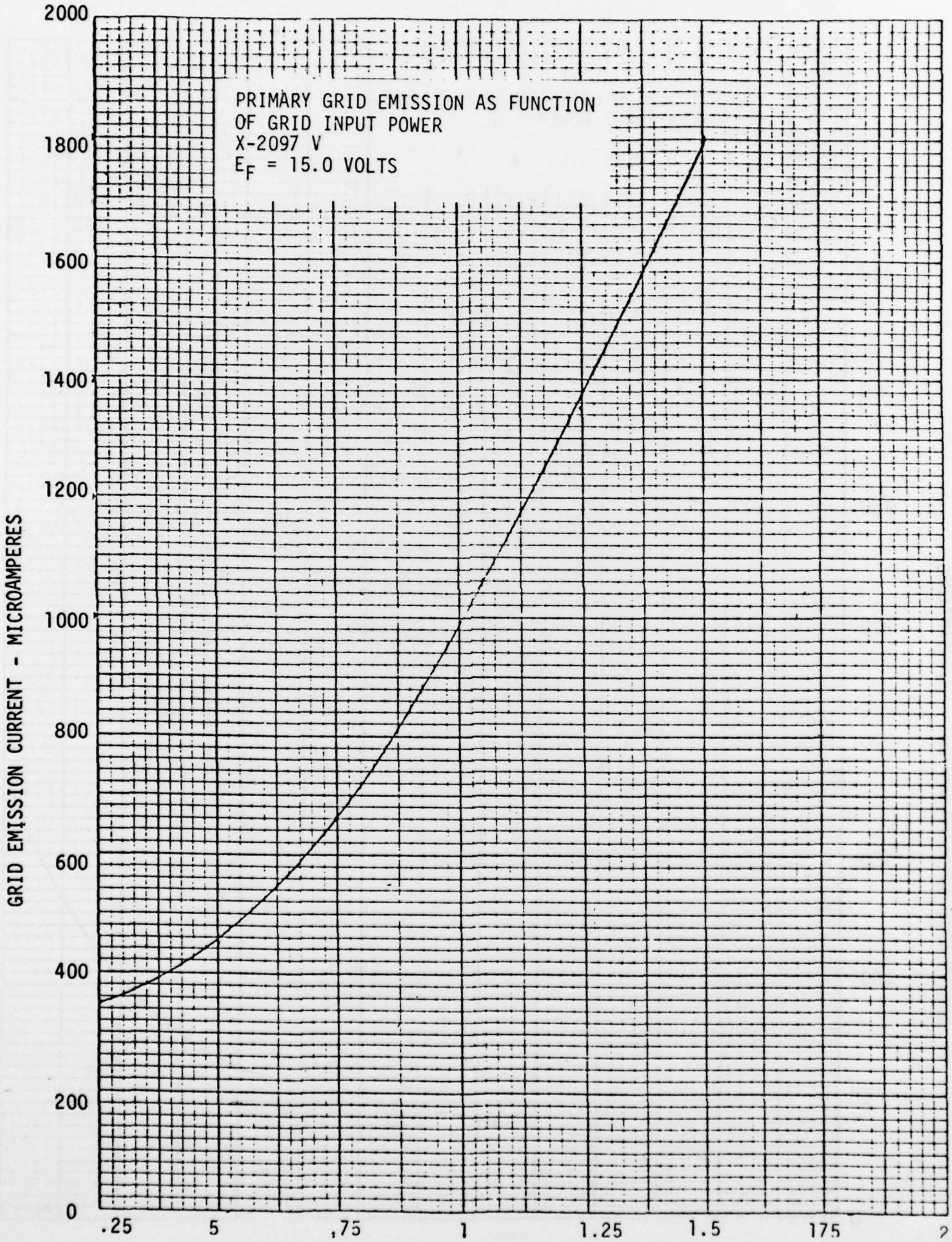


Fig. A12. 20907 KW GRID INPUT POWER-KW

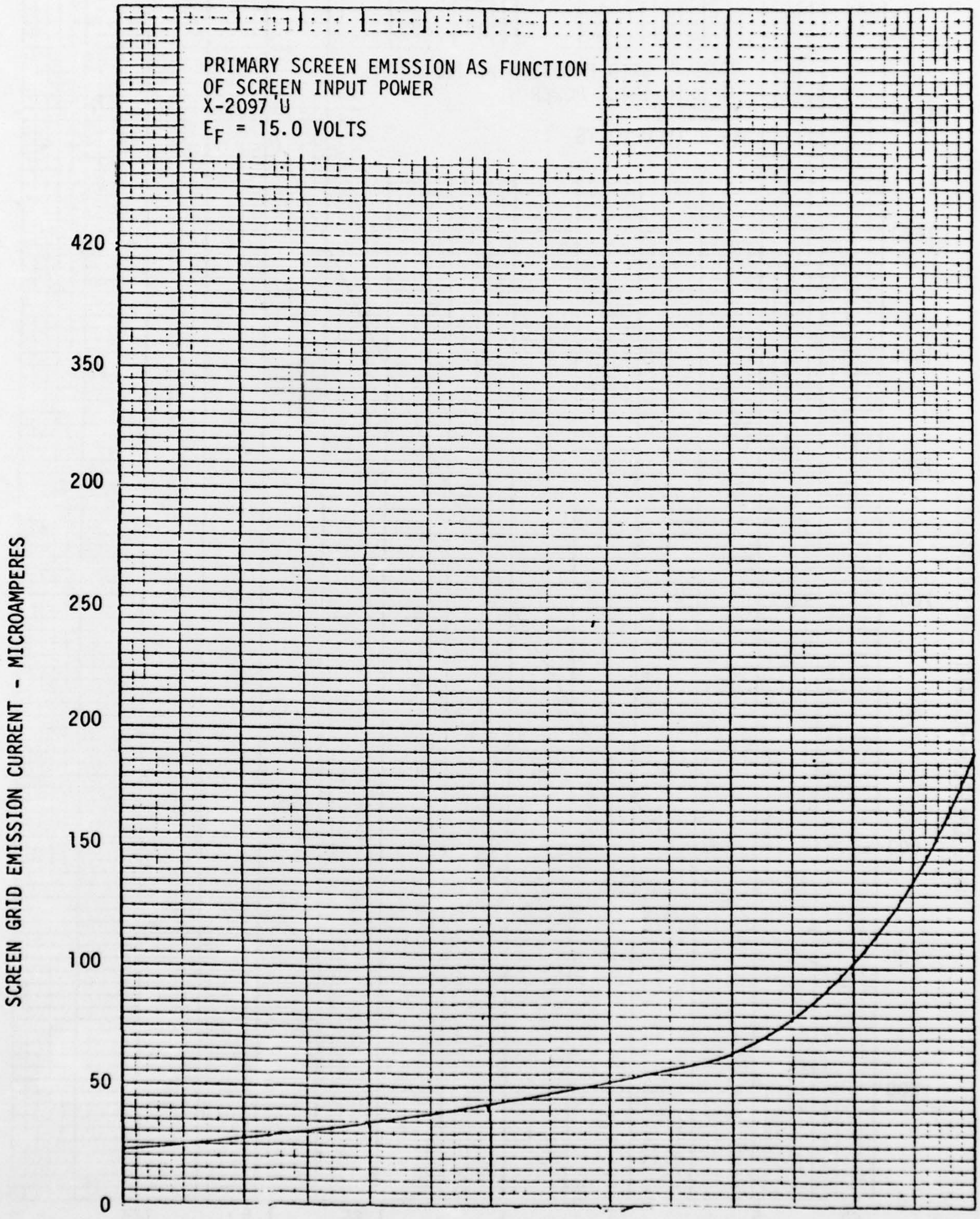


Fig. A13. X-2097 U SCREEN INPUT POWER - KW

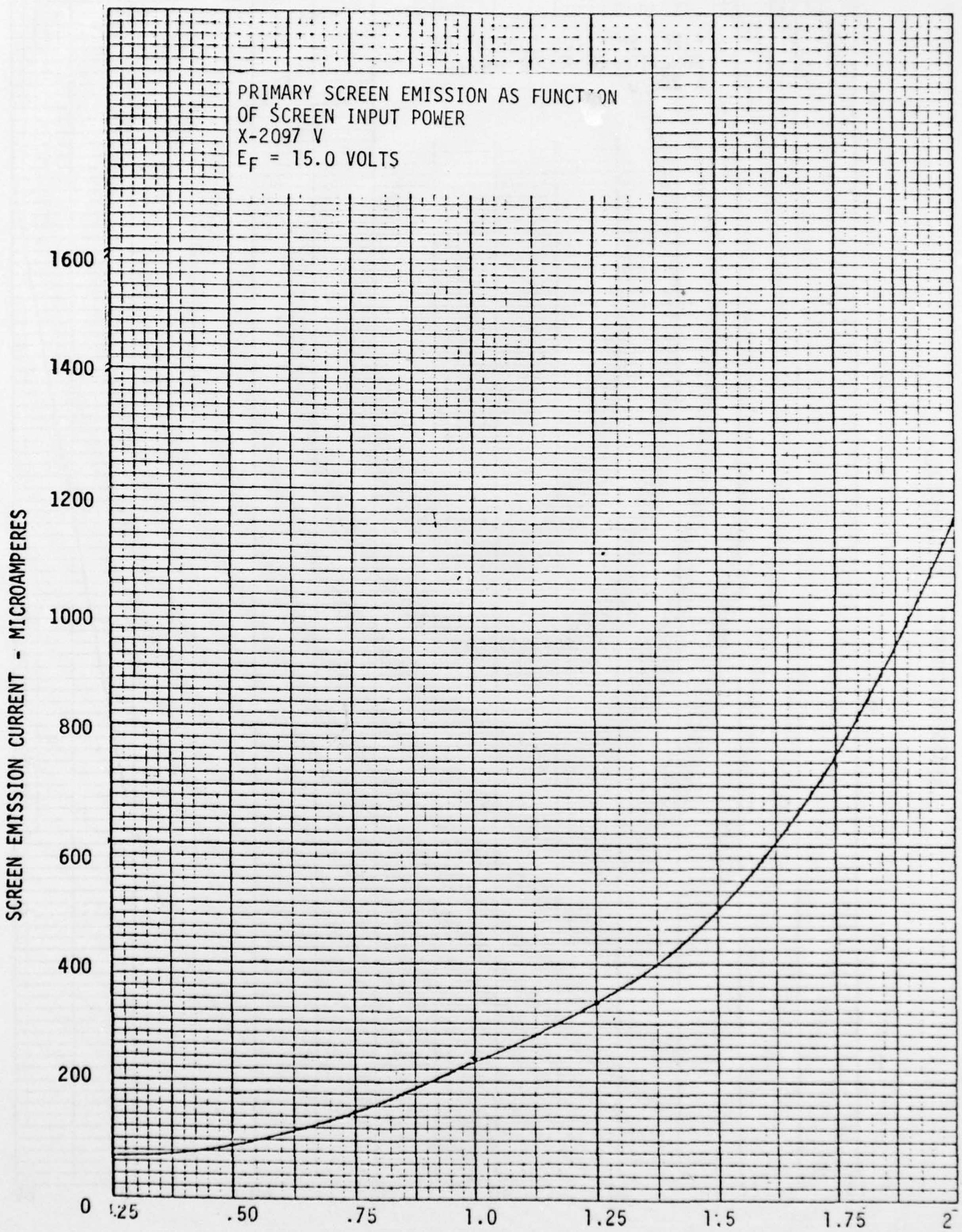


Fig A14. SCREEN INPUT POWER - KW

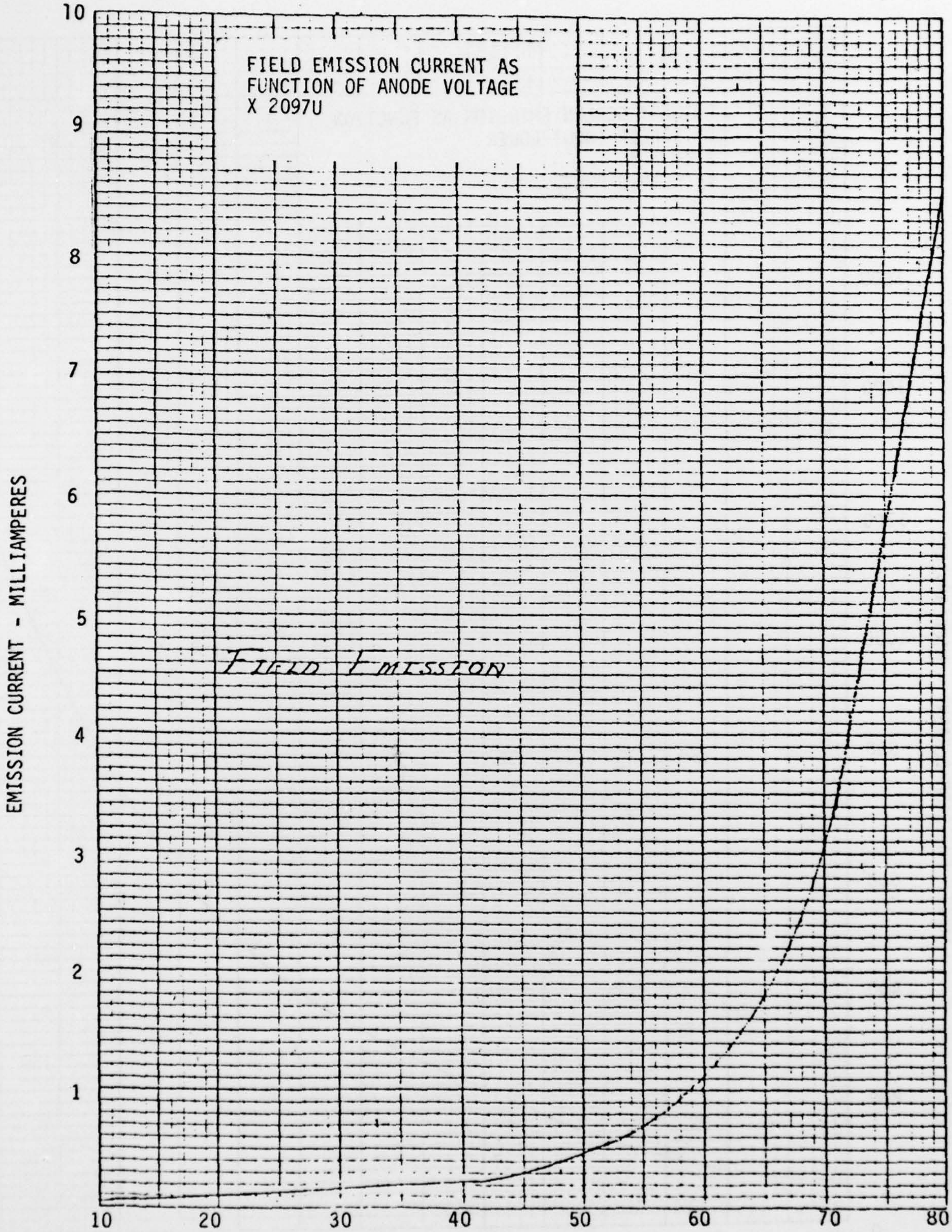


Fig. A15. ANODE KILOVOLTS

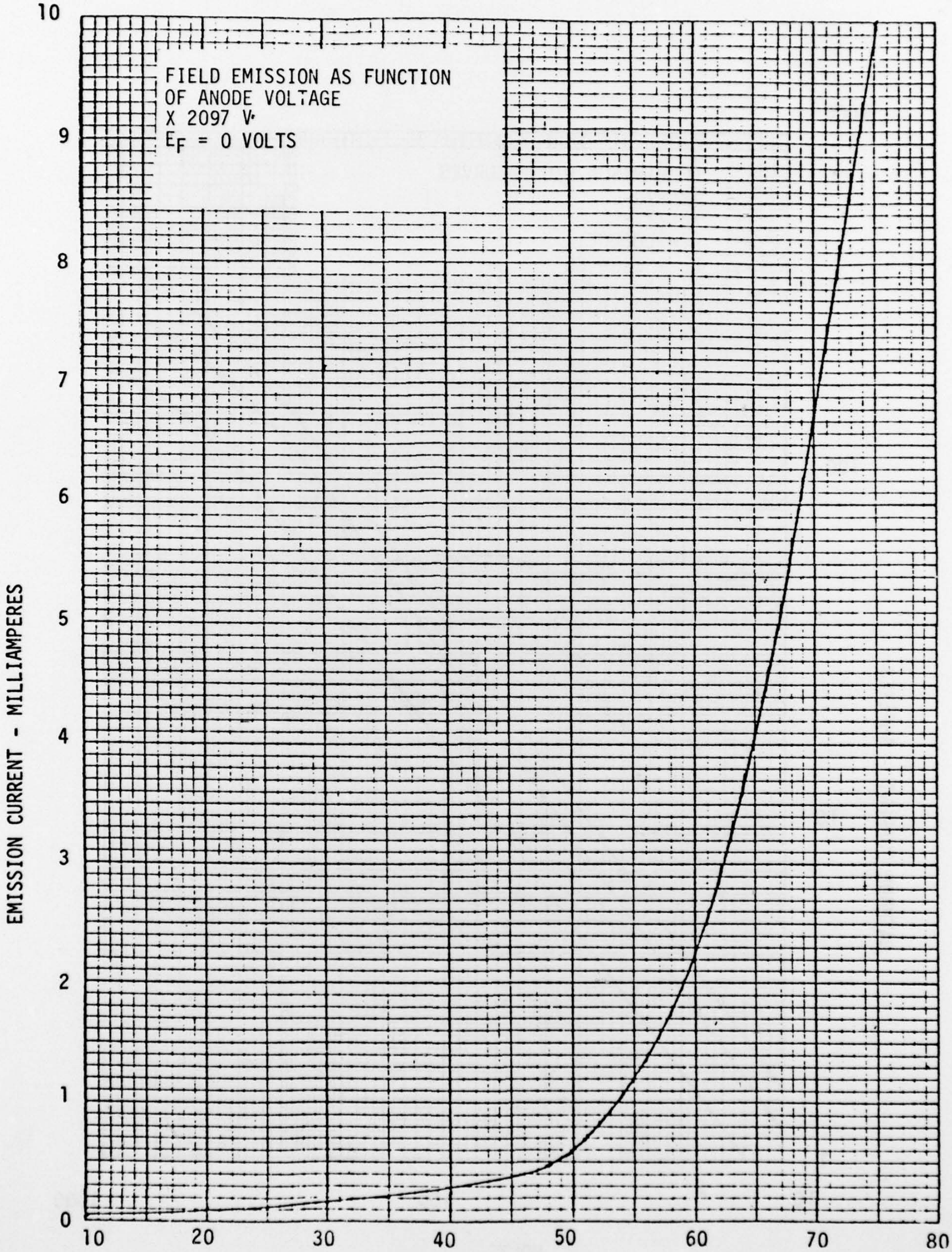
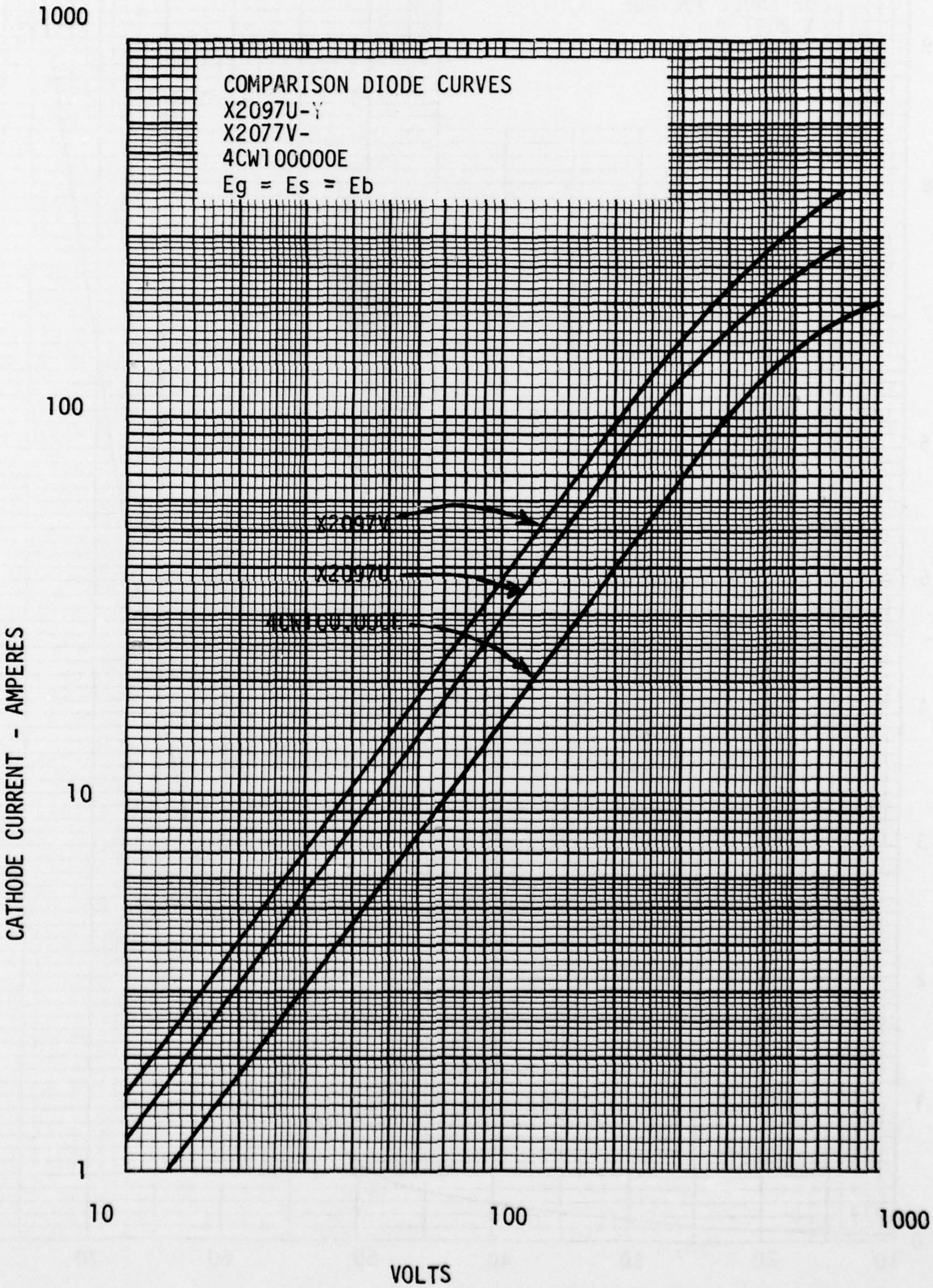
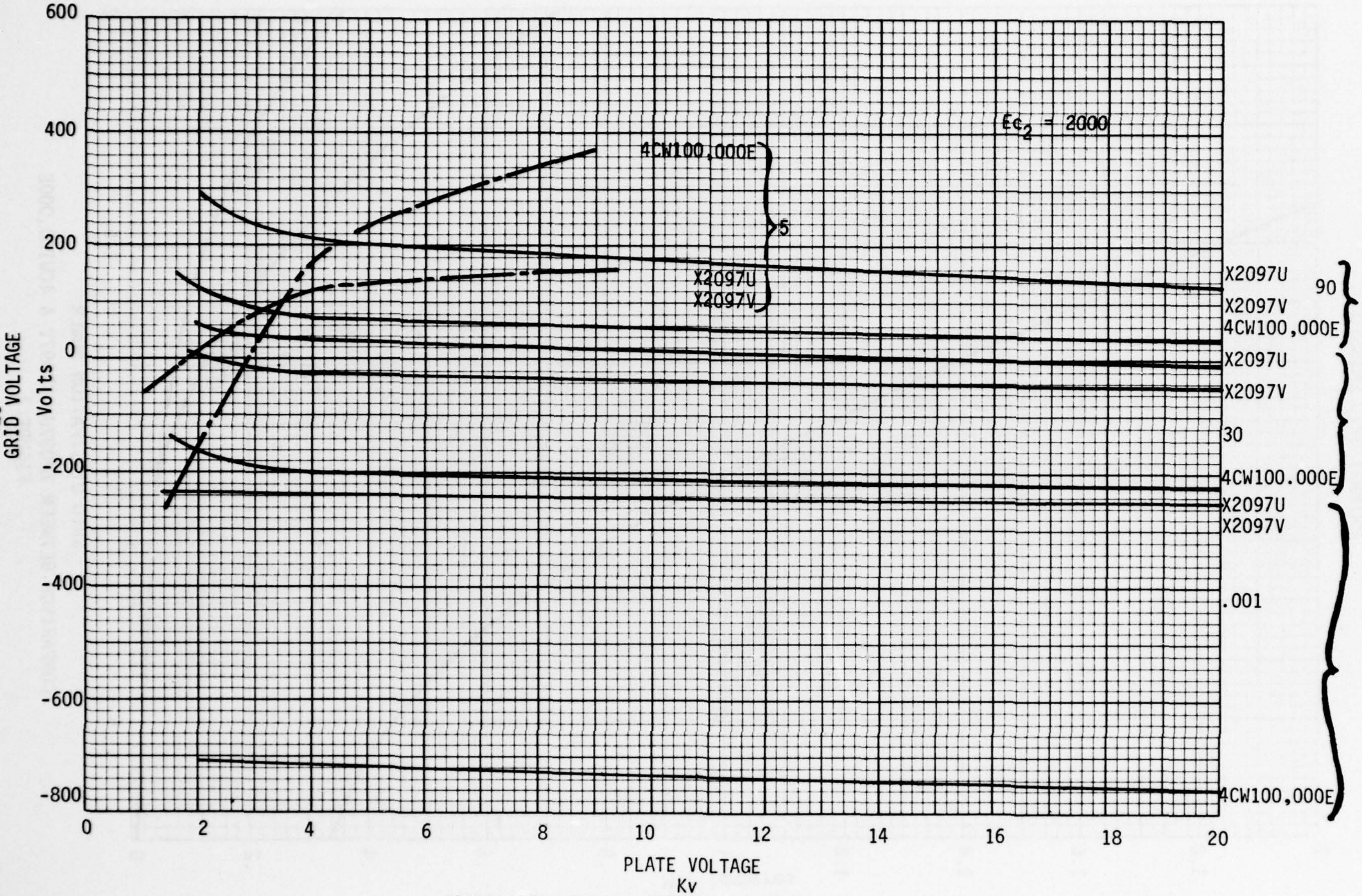


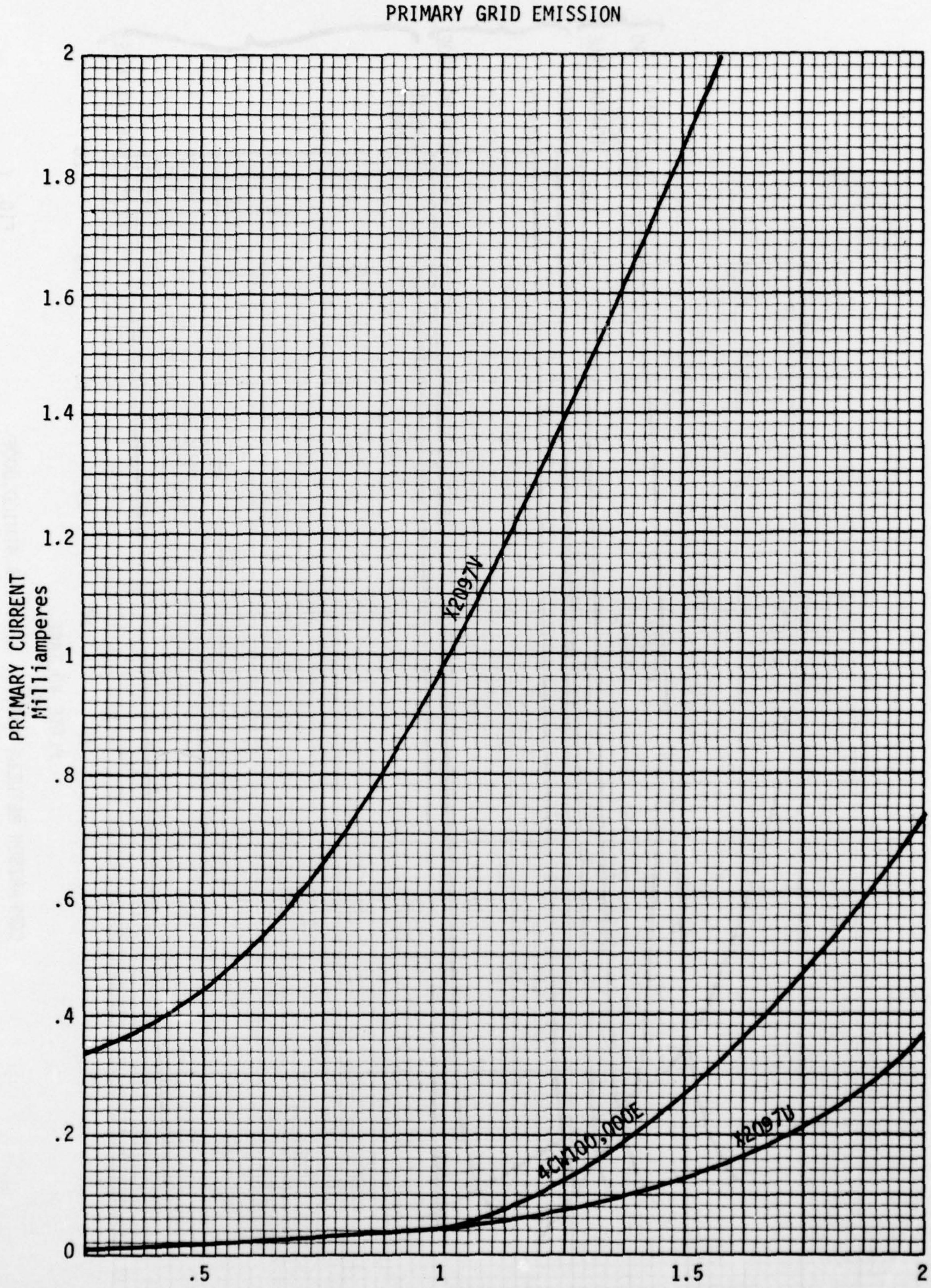
Fig. A16. ANODE KILOVOLTS


COMPARISON DIODE CURVES
X2097U-Y
X2077V-
4CW100000E
Eg = Es = Eb
X2097V
X2097U
4CW100,000E
1000
100
10
1
CATHODE CURRENT - AMPERES
10
100
1000
VOLTS



COMPARISON BETWEEN X2097U, X2097V & 4CW100,000E

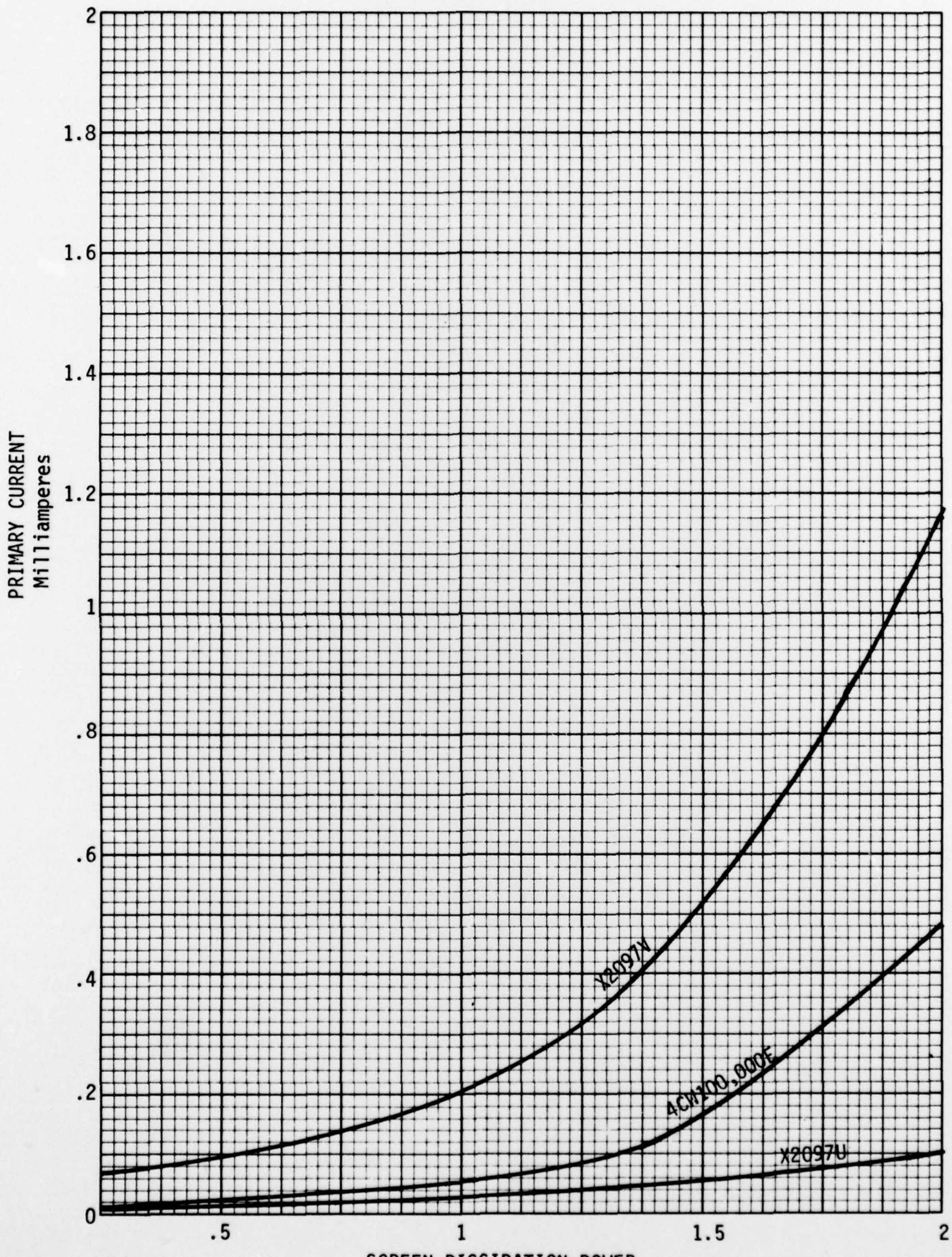
FIG. Y



COMPARISON BETWEEN X2097U, X2097V & 4CW100,000E

FIGURE Z

PRIMARY SCREEN EMISSION



COMPARISON BETWEEN X2097U, X2097V & 4CW100,000E

FIG. ZZ

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