X-2159

TECHNICAL DATA

WATER-COOLED
POWER TETRODE

The EIMAC X-2159 is a ceramic/metal, water-cooled power tetrode designed for very-high-powered medium-frequency or high-frequency broadcast service and very-low-frequency communication in the megawatt power range.

The X-2159 has a two-section thoriated-tungsten filament mounted on water-cooled supports. The two sections may be fed in quadrature to reduce hum contributed by an ac power source. The maximum anode dissipation rating is 1250 kilowatts steady state.

Large-diameter coaxial terminals are used for the control grid and the three rf filament terminals. Filament power and filament support cooling-water connections are made through three special couplings with knurled and threaded clamping rings.

GENERAL CHARACTERISTICS[1]

ELECTRICAL

Filament: Thoriated-tungsten, two-section		
Voltage per section	18.5 ± 0.9	V
Current at 18.5 V per section	700	A
Amplification Factor (Average), Grid to Screen	4.5	
Direct Interelectrode Capacitance (grounded cathode)[2]:		
Cin	1650	pF
Cout	260	pF
Cgp	10	pF
Direct Interelectrode Capacitance (grounded grid)[2]:		
Cin	675	pF
Cout	260	pF
Cpk	1.0	pF

Frequency of Operation: for use above 30 MHz, contact:
Product Manager, Power Grid Division, EIMAC Div. of Varian.

1. The design of this tube is subject to change. The data supplied is for guidance only. Before establishing a final equipment design with this tube, contact: Product Manager, Power Grid Division, EIMAC Division of Varian.

2. Capacitance values shown are nominal, measured with no special shielding.

Printed in U.S.A.

MECHANICAL

Maximum Overall Dimensions:	
Length	23.75 in; 60.32 cm
Diameter	17.03 in; 43.26 cm
Net Weight	175 lbs; 80 kg
Operating Position	Vertical, base down
Cooling	Water and Forced Air
Base Terminals	Special
Recommended Filament Connectors (not supplied with tube):	
Filament Power/Water Connector (3 required)	EIMAC X-2175
Filament rf Connector (1 required)	EIMAC X-2181
Maximum Operating Temperature:	
Envelope, and Ceramic/Metal Seals	200°C

RADIO FREQUENCY LINEAR AMPLIFIER GRID DRIVEN

Class AB

ABSOLUTE MAXIMUM RATINGS:

DC PLATE VOLTAGE	22.5	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC PLATE CURRENT	125	AMPERES
PLATE DISSIPATION	1250	KILOWATTS
SCREEN DISSIPATION	15	KILOWATTS
GRID DISSIPATION	4.0	KILOWATTS

TYPICAL OPERATION (Frequencies to 30 MHz)
Class AB1, Peak Envelope Conditions

Plate Voltage	20.0	kVdc
Screen Voltage	1500	Vdc
Grid Voltage [1]	-380	Vdc
Zero Signal Plate Current	20.0	Adc
Single Tone Plate Current	86.5	Adc
Single Tone Screen Current [2]	3.8	Adc
Peak rf Grid Voltage [2]	380	v
Plate Dissipation	505	kW
Plate Load Resistance	132.2	Ω
Plate Power Output	1225	kW
Efficiency	70.8	%

1. Adjust to specified zero-signal plate current.
2. Approximate value.

RADIO FREQUENCY POWER AMPLIFIER OR OSCILLATOR Class C Telegraphy or FM

(Key-down Conditions)

ABSOLUTE MAXIMUM RATINGS:

DC PLATE VOLTAGE	22.5	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC PLATE CURRENT	125	AMPERES
PLATE DISSIPATION	1250	KILOWATTS
SCREEN DISSIPATION	15	KILOWATTS
GRID DISSIPATION	4.0	KILOWATTS

TYPICAL OPERATION (Frequencies to 30 MHz)

Plate Voltage	21.5	kVdc
Screen Voltage	1000	Vdc
Grid Voltage	-700	Vdc
Plate Current	125	Adc
Screen Current [1]	12	Adc
Grid Current [1]	7.2	Adc
Calculated Driving Power	7.0	kW
Plate Dissipation [1]	530	kW
Screen Dissipation [1]	12	kW
Grid Dissipation [1]	1.9	kW
Plate Load Resistance	85.5	Ω
Plate Power Output	2158	kW
Efficiency	80.1	%

1. Approximate value.

PLATE MODULATED RADIO FREQUENCY POWER AMPLIFIER Class C Telephony

(Carrier Conditions)

ABSOLUTE MAXIMUM RATINGS:

DC PLATE VOLTAGE	17.5	KILOVOLTS
DC SCREEN VOLTAGE	2.0	KILOVOLTS
DC PLATE CURRENT	100	AMPERES
PLATE DISSIPATION	800	KILOWATTS
SCREEN DISSIPATION	15	KILOWATTS
GRID DISSIPATION	4.0	KILOWATTS

TYPICAL OPERATION (Frequencies to 30 MHz)

Plate Voltage	17.5	kVdc
Screen Voltage	1000	Vdc
Grid Voltage	-1000	Vdc
Plate Current	95.0	Adc
Screen Current [1]	8.0	Adc
Grid Current [1]	4.4	Adc
Pk. Screen Voltage (100% Mod)	1000	v
Pk. rf Grid Voltage	1280	v
Calculated Driving Power	6465	W
Plate Dissipation	279	kW
Screen Dissipation [1]	8.0	kW
Grid Dissipation [1]	2.05	kW
Plate Load Resistance	85.6	Ω
Plate Output Power	1384	kW
Efficiency	83.3	%

1. Approximate value.

AUDIO FREQUENCY POWER AMPLIFIER OR MODULATOR

Class AB

ABSOLUTE MAXIMUM RATINGS (per tube):

DC PLATE VOLTAGE	22.5	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC PLATE CURRENT	125	AMPERES
PLATE DISSIPATION	1250	KILOWATTS
SCREEN DISSIPATION	15	KILOWATTS
GRID DISSIPATION	4.0	KILOWATTS

TYPICAL OPERATION Two Tubes - Sinusoidal Wave

Plate Voltage	17.5	kVdc
Screen Voltage	1500	Vdc
Grid Voltage [1]	-455	Vdc
Zero Signal Plate Current	10	Adc
Max. Signal Plate Current	146.2	Adc
Max. Signal Screen Current [2]	7.8	Adc
Pk. Audio Freq. Grid Voltage [3]	455	v
Max. Signal Plate Dissipation [3]	275	kW
Plate/Plate Load Resistance	238.5	Ω
Plate Output Power	2015	kW

1. Adjust for stated zero-signal plate current.
2. Approximate value.
3. Per Tube.

NOTE: TYPICAL OPERATION data are obtained by calculation from the published characteristic curves. Adjustment of the rf grid voltage to obtain the specified plate current at the specified bias, screen, and plate voltages is assumed. If this procedure is followed, there will be little variation in output power then the tube is changed, even though there may be some variation in grid and screen current. The grid and screen currents which result when the desired plate current is obtained are incidental and vary from tube to tube. These current variations cause no difficulty so long as the circuit maintains the correct voltage in the presence of the variations in current.

APPLICATION

MECHANICAL

MOUNTING - The X-2159 must be mounted vertically, base down. The full weight of the tube should rest on the main screen-grid contact flange at the base of the tube, and all lifting of the tube should be done with the lifting eye which is attached to the top of the anode cooling jacket.

COOLING - It is essential that high purity water be used for anode cooling to minimize power loss and corrosion of metal fittings. Good distilled or de-ionized water will have a resistance of 1 to 2 megohms per cm^3. Water should be discarded if resistivity falls to 50,000 ohms/cm^3. Since the anode is normally

at high potential to ground, water connections to the anode are made through insulating tubing. These insulating sections should be long enough so that column resistance is above 100,000 ohms per 1000 plate supply volts. The table shows minimum anode cooling water requirements for several plate dissipation levels.

Plate Dissipation (Kilowatts)	Water Flow (GPM)	Pressure Drop (PSI)
500	130	15
800	205	30
1000	250	45
1250	310	66

This data is based on an inlet water temperature of 40°C and an outlet temperature of 70°C. In no case should the outlet water temperature be allowed to exceed 70°C, and system pressure should be limited to 85 PSI maximum.

Water cooling is also required for the screen grid, with a minimum flow of 2.0 GPM, at an approximate pressure drop of 25 PSI. The tube outline drawing shows which of the two connections should be used for inlet water.

Water cooling of the filament supports is required. Each of the three water connections includes both an inlet and outlet line, with the proper section for the inlet water shown on the outline drawing. Minimum flow for the F1 and F3 connectors should be 2.0 GPM, with an approximate pressure drop of 10 PSI for each connector; minimum flow for the F2 connector should be 4.0 GPM, with an approximate pressure drop of 55 PSI.

Base water cooling requirements can sometimes be simplified if the screen grid and filament connectors F1 and F3 are all cooled in series, with suitable insulation between terminals.

In addition to the water-cooling requirements, cooling air should be directed against the lower envelope surface, in the area of the ceramic/metal seals, and particularly from below, up into the recesses involving the control grid and screen grid contact surfaces. Under normal circumstances, a general purpose blower capable of supplying a minimum of one hundred CFM (at zero head), properly directed, will provide adequate cooling in the recessed base area. Temperatures of the ceramic/metal seals and the lower envelope areas are the controlling and final limiting factor. Temperature-sensitive paints are available for use in checking temperatures in these areas before equipment design and air-cooling arrangements are finalized.

All base cooling, air and water, *must* be applied before power is applied to the filaments. For standby operation, with no direct anode dissipation, a minimum flow of 5 GPM of anode cooling water is still required to prevent anode overheating, in addition to base cooling.

In all cases, both air-flow and water-flow interlocks should be used to remove all power from the tube in case of a cooling failure. However, cooling normally should be maintained for a brief period after all power is removed to allow for tube cool-down.

ELECTRICAL

FILAMENT OPERATION - Special procedures must be used in the application and removal of filament power. Cooling water flow *must* be on and at the correct level before any voltage is applied. Then a voltage of (approximately) 4 volts should be applied (per section), and held for a minimum of 30 seconds. Voltage can then be gradually increased until the full operating filament voltage level is achieved, but at no time should surge current be allowed to exceed 1600 amperes per section. To remove filament power, the voltage should be reduced gradually to (approximately) 4 volts and held at this level for a minimum of 30 seconds before all voltage is removed.

The peak emission capability at the rated, or nominal, filament voltage is normally many times that required for communication service. A small decrease in filament temperature due to a reduction of filament voltage can increase tube life by a substantial percentage. It is good practice to determine the nominal filament voltage for a particular application that will not affect the operation of the equipment. This is done by measuring some important parameter of performance, such as plate current, power output, or an increase in distortion, while filament voltage is reduced in small steps. At some value of filament voltage there will be a noticeable reduction in plate current or power output, or an increase in distortion. Operation should then be at a filament voltage slightly higher than the point at which performance degradation was

noted. The voltage should be measured at the tube base terminals with a 1% accuracy rms responding meter and periodically checked.

GRID OPERATION - The X-2159 grid is rated at 4000 watts of dissipation. Protective measures should be included in the circuitry to insure that this rating is not exceeded. Grid dissipation is the approximate product of dc grid current and peak positive grid voltage.

SCREEN OPERATION - Base cooling (air and water) must be on and at the correct level before tube operation is started. The power applied to the screen grid must not exceed 15 kilowatts. Where no ac is applied to the screen, dissipation is the product of dc screen voltage and dc screen current. With screen modulation the dissipation is the product of rms screen current and rms screen voltage.

Plate voltage, plate load, or grid bias voltage must never be removed while filament and screen voltages are present since the screen dissipation rating will be exceeded. Suitable protective circuitry must be provided to remove screen power in case of such a fault condition. Tetrode tubes may exhibit reversed screen current to a greater or lesser degree depending on individual tube design and operating conditions. The screen supply voltage must be maintained constant for any values of negative and positive screen currents that may be encountered. Dangerously high plate currents may flow if the screen power supply exhibits a rising voltage characteristic with negative screen current. Stabilization may be accomplished by use of a shunt regulator circuit in the screen voltage supply, or other suitable techniques.

PLATE OPERATION - The maximum dissipation rating of the X-2159 is 1250 kilowatts with water cooling. When used as a plate-modulated rf amplifier, plate dissipation under carrier conditions is limited to 800 kilowatts.

FAULT PROTECTION - In addition to the normal plate-overcurrent interlock, screen-current interlock, and coolant (both air and water) interlocks, it is good practice to protect the tube from internal damage caused by an internal plate arc which may occur at high plate voltages. An electronic crowbar, which will discharge power-supply capacitors in a few microseconds after the start of a plate arc, is recommended.

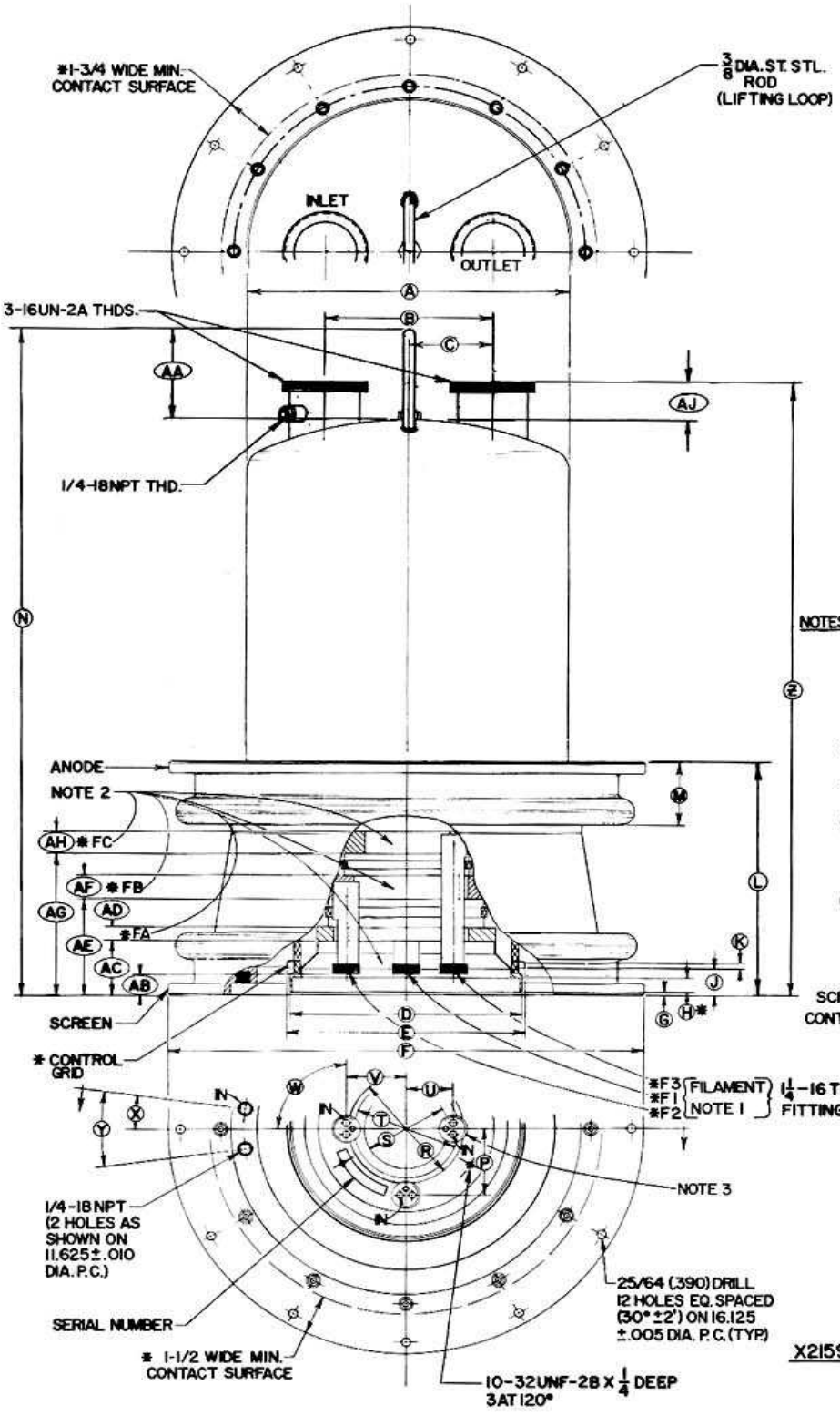
HIGH VOLTAGE - Normal operating voltages used with the X-2159 are deadly, and the equipment must be designed properly and operating precautions must be followed. Design all equipment so that no one can come in contact with high voltages. All equipment must include safety enclosures for high-voltage circuits and terminals, with interlock switches to open primary circuits of the power supply and to discharge high-voltage condensers whenever access doors are opened. Interlock switches must not be bypassed or "cheated" to allow operation with access doors open. Always remember that HIGH VOLTAGE CAN KILL.

X-RADIATION - High-vacuum tubes operating at voltages higher than 10 kilovolts produce progressively more dangerous X-ray radiation as the voltage is increased. The X-2159, operating at its rated voltages and currents, is a potential X-ray hazard. Only limited shielding is afforded by the tube envelope. Moreover, the X-ray radiation level can increase significantly with aging and gradual deterioration, due to leakage paths or emission characteristics as they are affected by the high voltage. X-ray shielding must be provided on all sides of tubes operating at these voltages to provide adequate protection throughout the tube's life. Periodic checks on the X-ray level should be made, and the tube should never be operated without adequate shielding in place when voltages above 10 kilovolts are in use. Lead glass, which attenuates X-rays, is available for viewing windows. If there is any doubt as to the requirement for or the adequacy of shielding, an expert in this field should be contacted to perform an X-ray survey of the equipment.

Operation of high-voltage equipment with interlock switches "cheated" and cabinet doors open in order to be better able to locate an equipment malfunction can result in serious X-ray exposure.

RADIO FREQUENCY RADIATION - Avoid exposure to strong rf fields even at relatively low frequency. Absorption of rf energy by human tissue is dependent on frequency. Under 30 MHz, most of the energy will pass completely through the human body with little attenuation or heating effect. Public health agencies are concerned with the hazard, however, even at these frequencies, and it is worth noting that some commercial dielectric heating units actually operate at frequencies as low as the 13 and 27 MHz bands.

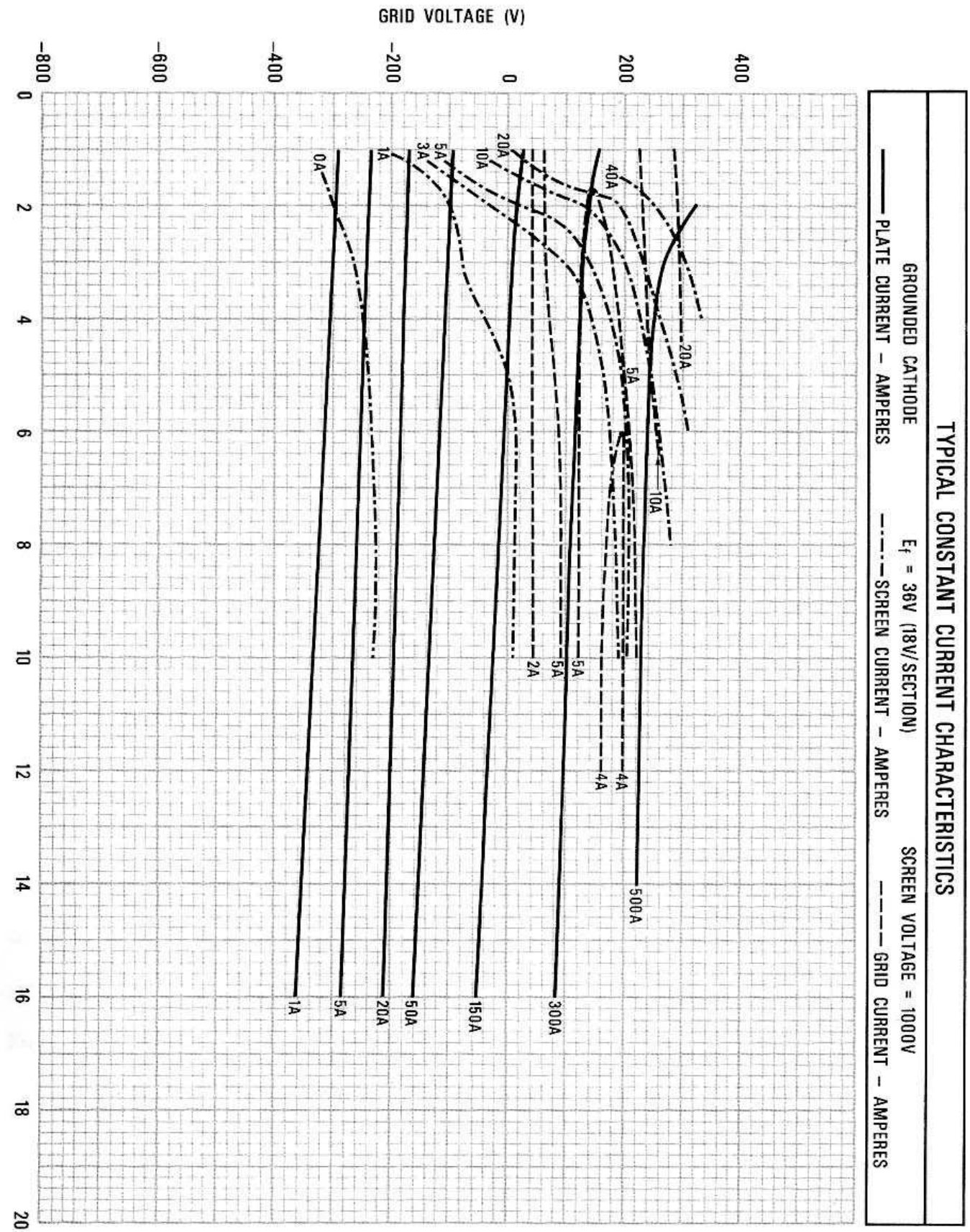
SPECIAL APPLICATION - Where it is desired to operate this tube under conditions widely different from those listed here, write to Power Grid Tube Product Manager, EIMAC Division of Varian, 301 Industrial Way, San Carlos, Ca. 94070, for information and recommendations.



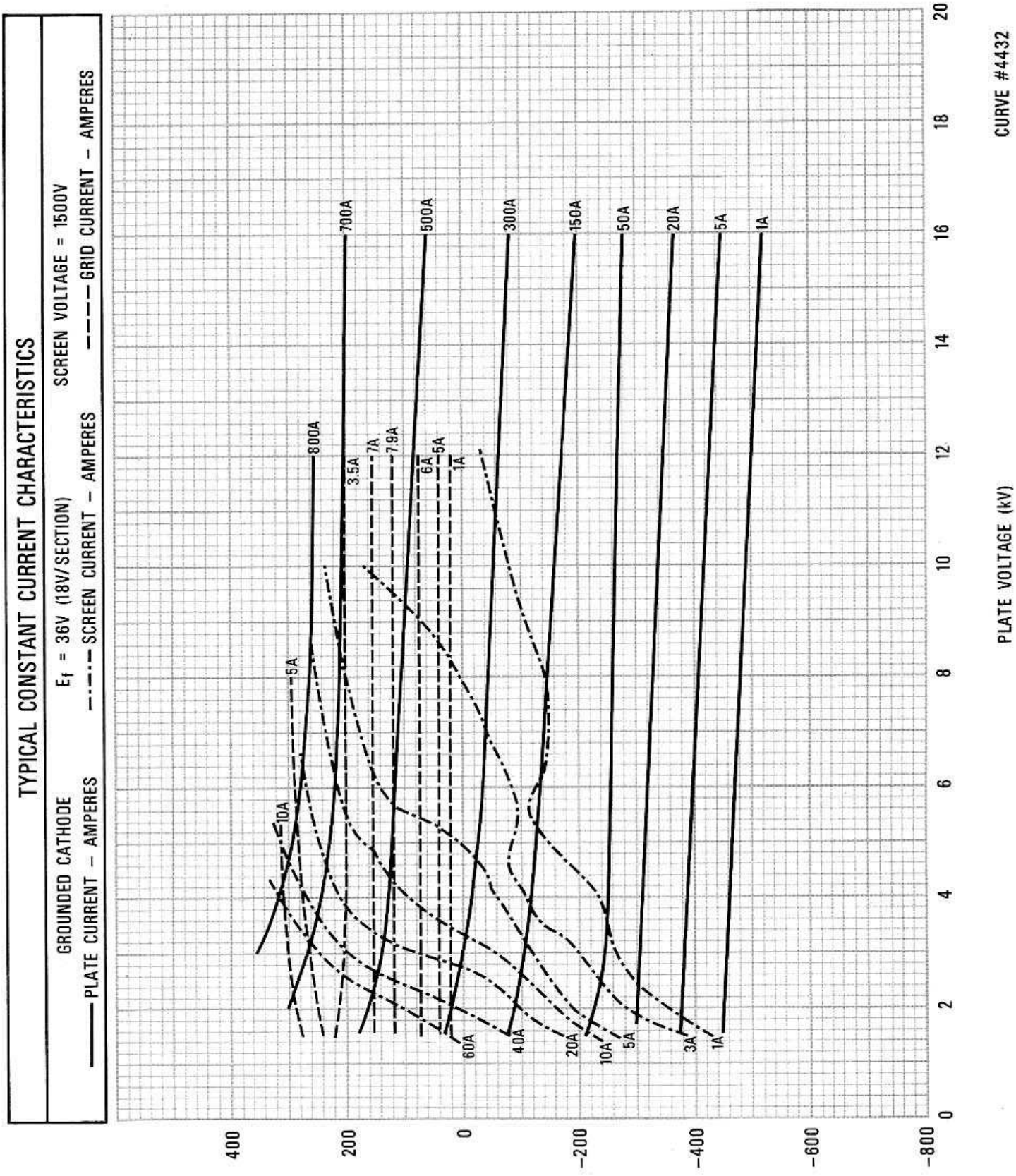
DIM	DIMENSIONAL DATA					
	INCHES			CENTIMETERS		
	MIN.	MAX.	REF.	MIN.	MAX.	REF.
A	11.440	11.560	- -	28.96	29.36	- -
B	- -	- -	6.000	- -	- -	15.24
C	- -	- -	3.000	- -	- -	7.62
D	8.235	8.265	- -	20.92	20.99	- -
E	8.485	8.525	- -	21.55	21.65	- -
F	16.970	17.030	- -	43.10	43.26	- -
G	- -	- -	0.025	- -	- -	0.063
H	0.310	- -	- -	0.79	- -	- -
J	0.900	1.000	- -	2.29	2.54	- -
K	0.180	- -	- -	0.46	- -	- -
L	8.700	8.900	- -	22.10	- -	- -
M	- -	- -	2.375	- -	- -	6.03
N	- -	- -	25.312	- -	- -	64.30
P	- -	- -	2.500	- -	- -	6.35
R	4.113	4.137	- -	10.45	10.51	- -
S	2.988	3.012	- -	7.59	7.65	- -
T	3.675	3.699	- -	9.33	9.40	- -
U	- -	- -	1.687	- -	- -	4.28
V	- -	- -	2.156	- -	- -	5.48
W	- -	- -	90°	- -	- -	90°
X	- -	- -	7-1/2°	- -	- -	7-1/2°
Y	- -	- -	15°	- -	- -	15°
Z	22.857	23.305	- -	58.06	59.19	- -
AA	- -	- -	3.575	- -	- -	9.08
AB	- -	- -	0.720	- -	- -	1.83
AC	1.960	2.100	- -	4.95	5.33	- -
AD	0.450	- -	- -	1.14	- -	- -
AE	3.560	3.680	- -	9.04	9.35	- -
AF	0.725	- -	- -	1.84	- -	- -
AG	5.300	5.450	- -	13.46	13.84	- -
AH	0.725	- -	- -	1.84	- -	- -
AJ	- -	- -	1.375	- -	- -	3.49

NOTES:
1. CIRCUIT RETURNS MAY BE MADE TO FA, FB, AND FC, WHICH ARE IN COMMON WITH F1, F2, AND F3, RESPECTIVELY.
2. FB AND FC CONTACT RINGS, IF USED, MUST HAVE CUT-OUTS FOR F2 AND F3.
3. MATE WITH EIMAC CONNECTOR X2175
4. DC RETURN SHOULD BE MADE TO F2 OR FB.
5. REF. DIMENSIONS ARE FOR INFO. ONLY & ARE NOT REQUIRED FOR INSPECTION PURPOSES.
6. (*) CONTACT SURFACES

X2159 POWER TETRODE


TYPICAL CONSTANT CURRENT CHARACTERISTICS
GROUNDED CATHODE
E_f = 36V (18V/SECTION)
SCREEN VOLTAGE = 1000V
PLATE CURRENT – AMPERES
SCREEN CURRENT – AMPERES
GRID CURRENT – AMPERES
GRID VOLTAGE (V)
PLATE VOLTAGE (KV)
400
200
0
−200
−400
−600
−800
0
2
4
6
8
10
12
14
16
18
20
20A
10A
5A
40A
4A
4A
500A
5A
5A
2A
300A
20A
10A
5A
3A
1A
150A
0A
50A
20A
5A
1A

CURVE #4417


TYPICAL CONSTANT CURRENT CHARACTERISTICS
GROUNDED CATHODE
E_f = 36V (18V/SECTION)
SCREEN VOLTAGE = 1500V
PLATE CURRENT – AMPERES
SCREEN CURRENT – AMPERES
GRID CURRENT – AMPERES
GRID VOLTAGE (V)
PLATE VOLTAGE (kV)
CURVE #4432
800A
700A
500A
300A
150A
50A
20A
5A
1A
10A
5A
3.5A
7A
7.9A
6A
5A
1A
60A
40A
20A
10A
5A
3A
1A
400
200
0
-200
-400
-600
-800
0
2
4
6
8
10
12
14
16
18
20