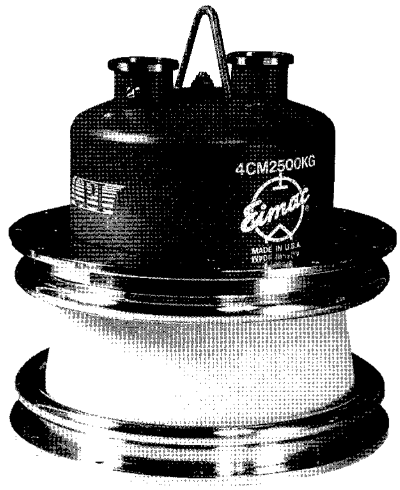

TECHNICAL DATA

MULTI-PHASE COOLED POWER TETRODE 4CM2500KG

The EIMAC 4CM2500KG is a ceramic/metal, multi-phase (water/vapor) cooled power tetrode designed for very high power rf service.

The 4CM2500KG has a high density thoriated tungsten mesh filament mounted on water-cooled supports. Pyrolytic graphite control and screen grids are used to provide stability at high dissipation. The maximum anode dissipation rating is 2500 kilowatts.

Large diameter coaxial control grid and cathode terminals allow enhanced VHF performance. Filament power and filament support cooling water are supplied through slip-fit connectors which allow for quick tube installation and replacement.

GENERAL CHARACTERISTICS

ELECTRICAL

Filament: Thoriated-tungsten Mesh
- Voltage 15.5V
- Current @ 15.5 volts (nominal) .... 640 A

Frequency of Maximum Ratings (CW) .... 130 MHz

Maximum Useful Frequency .... Over 200 MHz

Amplification Factor, Average, Grid to Screen 6

Direct Interelectrode Capacitances (grounded cathode):
- Cin .... 1100 pF
- Cout .... 150 pF
- Cgp .... 5.5 pF

Direct Interelectrode Capacitances (grounded grid)
- Cin .... 385 pF
- Cout .... 152 pF
- Cpk .... 0.7 pF

MECHANICAL

Net Weight .... 153 lb; 69.5 kg

Operating Position .... Vertical, Base Down

Cooling .... Water and Forced Air

Maximum Overall Dimensions:
- Length .... 18.75 in; 47.62 cm
- Diameter .... 17.03 in; 43.26 cm

Maximum Operating Temperature,
- Envelope and Ceramic/Metal Seals .... 200°C

Available Filament Power Connector (not supplied with tube):
- Filament Power/Water Connector (2 required): EIMAC SK-2310
- Filament rf Connector (1 required): EIMAC SK-2315

Available Anode Cooling Water Connectors (not supplied with tube):
- Note: 2 connectors are required per tube EIMAC SK-2322 or EIMAC SK-2223

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RADIO FREQUENCY POWER AMPLIFIER
GROUNDED GRID - Drive Pulsed
For long pulse fusion applications or CW Service (see PLATE OPERATION)

(Class AB or B)

ABSOLUTE MAXIMUM RATINGS:

DC PLATE VOLTAGE	27	Kilovolts
DC SCREEN VOLTAGE:	2.5	Kilovolts
PLATE CURRENT #	190	Amperes
PLATE DISSIPATION	2500	Kilowatts
SCREEN DISSIPATION	20	Kilowatts
GRID DISSIPATION	8.0	Kilowatts

Average during the pulse
* Approximate

TYPICAL OPERATION:

Plate-to-grid Voltage	24	24	24	kVdc
Screen-to-grid	1000	1500	2000	Vdc
Bias Voltage	490	500	540	Vdc
Plate Current #	86.7	127	182	Adc
Plate Dissipation	441	728	1550	kW
Screen Current #	5.8	7.5	4.1	Adc
Screen Dissipation	10.1	16.9	11.3	kW
Grid Current #	10.3	10.0	6.1	Adc
Drive Power#*	69.9	98.3	138.0	Kw
Input Impedance				Ohms
Plate Load Impedance	145	102	74	Ohms
Power Output #*	1700	2400	3500	kW

APPLICATION

MECHANICAL

MOUNTING - The 4CM2500KG must be mounted vertically, base down. The full weight of the tube should rest on the 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.

ANODE COOLING - The anode is cooled by circulating high velocity water through the structure. Water cooling provides efficient removal of heat from the anode and assures additional capacity for temporary overloads.

Tube life can be seriously compromised by the condition of the cooling water. If it becomes contaminated, deposits will form on the inside of the water jacket causing localized anode heating and eventual tube failure. To insure minimum electrolysis and power loss, the water resistance at 25°C should always be one megohm per cubic centimeter or higher. The relative water resistance can be continuously monitored in the reservoir by readily available instruments.

High velocity water flow is required to maintain high thermal efficiency. Cooling water must be well filtered, with effectiveness the equivalent of a 100-mesh screen, to eliminate any solid material and avoid the possibility of blockage of any cooling passages, as this would immediately affect cooling efficiency and could produce localized anode overheating and failure of the tube.

Minimum water flow requirements for the anode are shown in the table for an outlet water temperature not to exceed 100°C and inlet water temperature at 50°C. System pressure should not exceed 100 psi.

Anode Dissipation (kW)	Water Flow (gpm)	Approx. Jacket Press Drop (psi)
0 to 375	30	3
500	40	4.8
1000	77	14.2
1250	96	21
1500	115	31
2000	153	55
2500	190	87

EIMAC Application Bulletin #16, WATER PURITY REQUIREMENTS IN LIQUID COOLING SYSTEMS, is available on request and contains considerable detail on purity requirements and maintenance systems.

BASE COOLING - The tube base requires air cooling with a minimum of 50 cfm of air at 50°C maximum at sea level, directed toward the base seal areas from a general purpose fan. It should be noted that 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 requirements are finalized. Application Bulletin #20 TEMPERATURE MEASUREMENTS WITH EIMAC POWER TUBES is available on request.

Water cooling of the filament and screen grid supports is also required, with inlet water temperature not to exceed 50°C. Each of the two filament connectors include both an inlet and an outlet line, with the proper connector for the inlet water shown on the tube outline drawing. Minimum flow for the F1 connector is 2.0 gpm, at an approximate pressure drop of 12 psi. Minimum flow for the F2 connector is 4.0 gpm, at an approximate pressure drop of 50 psi. The screen grid cooling water is fed by means of 1/4-18 NPT tapped holes shown on the tube outline drawing, with a minimum flow of 2.0 gpm required, at an approximate pressure drop of 12 psi.

ALL COOLING MUST BE APPLIED BEFORE OR SIMULTANEOUSLY WITH THE APPLICATION OF ELECTRODE VOLTAGES, INCLUDING THE FILAMENT, AND SHOULD NORMALLY BE MAINTAINED FOR SEVERAL MINUTES AFTER ALL VOLTAGES ARE REMOVED TO ALLOW FOR TUBE COOLDOWN.

ELECTRICAL

ABSOLUTE MAXIMUM RATINGS - Values shown for each type of service are based on the "absolute system" and are not to be exceeded under any service conditions. These ratings are limited values outside which serviceability of the tube may be impaired. In order not to exceed absolute ratings the equipment designer has the responsibility of determining an average design value for each rating below the absolute value of that rating by a safety factor so that the absolute values will never by exceeded under any usual conditions of supply-voltage variation, load variation, or manufacturing variation in the equipment itself. It does not necessarily follow that combinations of absolute maximum ratings can be attained simultaneously.

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

FILAMENT OPERATION - Filament turn-on and turn-off should be programmed. Filament voltage should be smoothly increased from zero to the operating level over a period of two minutes, and a motor-driven continuously variable auto-transformer (such as a VARIAC® or a POWERSTAT®) is suggested. Inrush current must never be allowed to exceed twice normal operating current. Normal turnoff procedure should be a smooth decrease from the operating voltage to zero over a period of two minutes.

During periods of standby service, filament life may be increased by a small reduction in filament voltage. Black heat operation (a reduction of filament voltage to 50% or less of nominal voltage) is not recommended with this product. A minimum cooling water flow of at least 1.0 gpm is required through all cooling circuits (including the anode) during standby operation.

Filament voltage should be measured at the tube base, using an accurate rms-responding meter.

Where hum is an important system consideration, it is permissible to operate the filaments with dc rather than ac power. Contact EIMAC Application Engineering for special precautions when using a dc filament supply.

Care should be exercised to keep any rf power out of the filament of the tube, as this can cause excessive operating temperatures. Both sides of the filament must be bypassed to assure monopotential operation. It should be ascertained that no resonance exists in the filament circuit which could be excited during operation. When this tube is operated at combined screen and grid dissipations above 10 kilowatts then filament power should be reduced to maintain filament temperature (i.e., resistance) and thereby assure optimum life. Contact EIMAC Applications Engineering for specific recommendations.

This tube is designed for commercial service, with only one off/on filament cycle per day. If additional cycling is anticipated, it is recommended the user contact EIMAC Applications Engineering for additional information.

VACION® PUMP OPERATION - The tube is supplied with an ion pump and magnet, mounted on the filament structure at the base (stem). A power supply (Varian Part #924-0015) and a 8-foot cable (Varian Part #924-0020) are required for operation. The primary function of this device is to allow monitoring of the condition of the tube vacuum, as shown by an ion current meter.

With an operational tube it is recommended the VACION pump be operated full time so tube vacuum may be monitored on a continuous basis. A reading of less than 10 uAdc should be considered as normal, indicating excellent tube vacuum. In addition to other interlock circuitry it is recommended that full advantage be taken of the VACION pump readout by providing circuitry which will shut down all power to the tube in the event the readout current exceeds 50 uAdc. In the event of such a shutdown, the VACION pump should be operated alone until vacuum recovery is indicated by a reading of 10 uAdc or less, at which point the tube may again be made operational. If the vacuum current rises again it should be considered as indicating a circuit problem such that some tube element may be over-dissipating and outgassing.

In the case of a spare tube (non-operational) it is recommended the VACION pump be operated continuously if possible. Otherwise it should be operated periodically to check the condition of tube vacuum, and operated as long as necessary to achieve a reading of 10 uAdc or better.

Figure 1 shows the relationship between tube vacuum and the ion current reading. Electrode voltages, including filament voltage, should never be applied if a reading of 50 uAdc or higher is obtained. In the event that poor vacuum cannot be improved by operation of the VACION pump the user should contact EIMAC and review the case details with an Applications Engineering specialist.

PLATE OPERATION - The 2500 kW plate dissipation maximum rating may be exceeded for very brief periods during setup or tuning.

Anode current which flows at high plate voltages with no rf, such as interpulse idling current, must be avoided by such means as reducing screen voltage or increasing bias during the "idling" interval. Current flowing at high anode voltage causes significant X-Ray generation. At typical Class AB idling currents X-Ray intensity is very high, a significant personnel hazard. In addition tube anode damage can be caused by high voltage "idling" current.

Operation with significant plate current under some conditions of high instantaneous anode voltage (such as regulator service or lower power and low impedance "tuning" conditions) can, as a result of the screen and grid voltages chosen, lead to anode damage and subsequent failure. If operation under such conditions is necessary EIMAC Application Engineering should be contacted for assistance in selection of operating parameters.

GRID OPERATION - The maximum grid dissipation is 8000 watts and protective measures should be taken in insure that this rating is not exceeded. Grid dissipation is approximately equal to the product of dc grid current and peak positive grid voltage. A protective spark gap device should be connected between the control grid and the cathode to guard against excessive voltage.

SCREEN OPERATION - The maximum screen grid dissipation is 20,000 watts. With no ac applied to the screen grid, dissipation is simply the product of dc screen voltage and the dc screen current. Rf heating of the screen must be measured in calculating total screen dissipation at frequencies greater than 60 MHz. CONTACT EIMAC APPLICATIONS ENGINEERING DEPARTMENT FOR TYPICAL METHODS OF CALCULATING THE RF CONTRIBUTION TO SCREEN HEATING. Plate voltage, plate loading, or bias voltage must never be removed while filament and screen voltages are present, since screen dissipation ratings will be exceeded. Suitable protective circuitry must be provided to remove screen power in case of a fault condition. A protective spark-gap device should be connected between screen grid and the cathode to guard against excessive voltage.

Operation of the 4CM2500KG at its maximum VHF power capabilities will result in sufficient rf current screen grid heating to cause significant reverse screen grid current due to thermionic emission. Such operation will not cause tube damage if proper procedures are followed; however, the screen grid circuit must be designed to absorb the reverse current without allowing the screen grid voltage to rise excessively. Further questions on this subject should be directed to the Application Engineering group at EIMAC.

PULSE OPERATION - The thermal time constants of the internal tube elements vary from a few milliseconds in the case of the grids to about 200 milliseconds for the anode. In many applications the meaning of duty as applied to a pulse chain is lost because the interpulse period is very long. For pulse lengths greater than 10 milliseconds, where the interpulse period is more than 10 times the pulse duration, the element dissipations and required cooling are governed by the watt-seconds during the pulse. Provided the watt-seconds are less than the listed maximum dissipation rating and sufficient cooling is supplied, tube life will not be compromised. To maintain high cooling efficiency the anode water flow must be sufficient to insure turbulent flow. See Flow Chart on Page 2.

FAULT PROTECTION - In addition to the normal plate over-current interlock and coolant interlock, the tube must be protected from internal damage caused by any arc which may occur. A protective resistance should always be connected in series with the grid and anode to help absorb power supply stored energy if an arc should occur. An electronic crowbar, which will discharge power supply capacitors in a few microseconds after the start of an arc, is required. The protection criteria for each supply is to short each electrode to ground, one at a time, through a vacuum relay switch and a 6-inch length of #30 AWG copper wire. The wire will remain intact if criteria is met.

As noted under GRID OPERATION and SCREEN OPERATION, a protective spark gap should be connected from the control grid to ground and from the screen grid to ground.

EIMAC Application Bulletin #17 titled FAULT PROTECTION contains considerable detail and is available on request.

LOAD VSWR - The load VSWR should be monitored and the detected signal used to operate the interlock system to remove plate voltage within 20 milliseconds after a fault occurs. In the case of high stored energy in the load system, care must be taken to avoid excessive return energy from damaging the tube and associated circuit components.

MODE SUPPRESSION CONSIDERATIONS - High-performance high-power gridded tubes (such as the 4CM2500KG) have natural circular resonance modes which must be suppressed during initial testing of equipment. The short compact stem structure of EIMAC tubes provides easy access for mode suppression techniques. It is recommended that short pulse testing be used to detect this phenomenon and to evaluate the effectiveness of the suppression techniques used.

The 4CM2500KG has been found to exhibit circular mode oscillations in both L band and S band frequency ranges. The circular modes must be suppressed externally to prevent damage to the tube and to provide stable operation in the intended application. One technique which has worked to suppress these circular modes is using ferrite tiles. The ferrite tiles can be cemented (using General Electric RTV-102 or equivalent) to the conical and flat surfaces of the "screen deck" at the base of the tube. The size of the tiles can be up to approximately one inch square or rectangular and 0.1 to 0.3 inch thick. The ferrite must have properties such that it is not lossy at the fundamental frequency otherwise excessive heating of the ferrite may occur. One source for the ferrite material is: National Magnetics Group, Inc. in Bethlehem, PA, USA. For further information contact CPI - EIMAC Applications Engineering.

X-RADIATION HAZARD - High-vacuum tubes operating at voltages higher than 15 kilovolts produce progressively more dangerous X-ray radiation as the voltage is increased. This tube, operating at its rated voltages and currents, is a potential X-ray source. Only limited shielding is afforded by the tube envelope. Moreover, the X-radiation level may increase significantly with tube aging and gradual deterioration, due to leakage paths or emission characteristics as they are effected by the high voltage. X-ray shielding may be required on all sides of tubes operating at these voltages to provide adequate protection throughout the life of the tube. Periodic checks on the X-ray level should be made, and the tube should never be operated without required shielding in place. If there is any question as to the need for or the adequacy of shielding, an expert in this field should be contacted to perform an X-ray survey. In cases where shielding has been found to be required, operation of 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. OSHA (Occupational Safety and Health Administration) recommends that prolonged exposure to rf radiation should be limited to 10 milliwatts per square centimeter.

INTERELECTRODE CAPACITANCE - The actual internal interelectrode capacitance of a tube is influenced by many variables in most applications, such as stray capacitance to the chassis from the tube terminals and associated wiring. To control the actual capacitance values within the tube, as the key component involved, the industry and military services use a standard test procedure described in Electronic Industries Association Standard RS-191. The test is performed on a cold tube, and in the case of the 4CM2500KG, with no special shielding. Other factors being equal, controlling internal tube capacitance in this way normally assures good interchangeability of tubes over a period of time. The capacitance values shown in the test specification or technical data are taken in accordance with Standard RS-191.

The equipment designer is cautioned to make allowance for the capacitance values, including tube-to-tube variation and strays, which will exist in any normal application. Measurements should be taken with mounting which represent approximate final layout if capacitance values are highly significant in the design.

SPECIAL APPLICATIONS - When it is desired to operate this tube under conditions different from those listed here, write to CPI EIMAC, ATTN: Applications Engineering; 301 Industrial Way, San Carlos, CA 94070 USA.

OPERATING HAZARDS

Proper use and safe operating practices with respect to power tubes are the responsibility of equipment manufacturers and users of such tubes. All persons who work with or are exposed to power tubes or equipment which utilizes such tubes must take precautions to protect themselves against possible serious bodily injury. Do not be careless around such products.

Operation of this tube may involve the following hazards, any one of which, in the absence of safe operating practices and precautions, could result in serious harm to personnel.

HIGH VOLTAGE - Normal operating voltages can be deadly. Remember that HIGH VOLTAGE CAN KILL.

LOW-VOLTAGE HIGH-CURRENT CIRCUITS - Personal jewelry, such as rings, should not be worn when working with filament contacts or connectors as a short circuit can produce very high current and melting, resulting in severe burns.

RF RADIATION - Exposure to strong rf fields should be avoided, even at relatively low frequencies. The dangers of rf radiation are more severe at UHF and microwave frequencies. CARDIAC PACEMAKERS MAY BE EFFECTED.

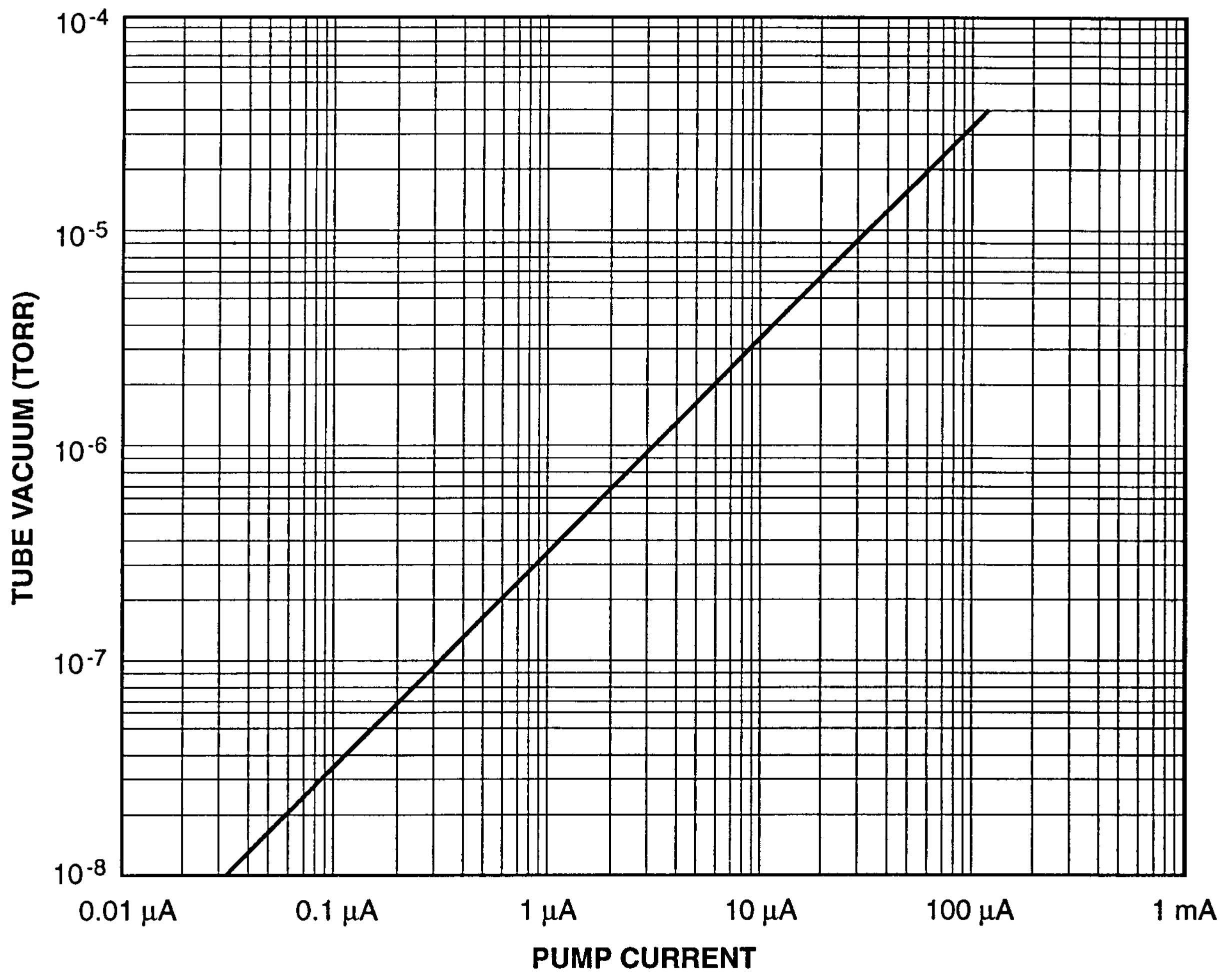
HOT WATER - Water used to cool tubes may reach scalding temperatures. Touching or rupture of the cooling system can cause serious burns.

HOT SURFACES - Surfaces of tubes can reach temperatures of several hundred °C and cause serious burns if touched for several minutes after all power is removed.

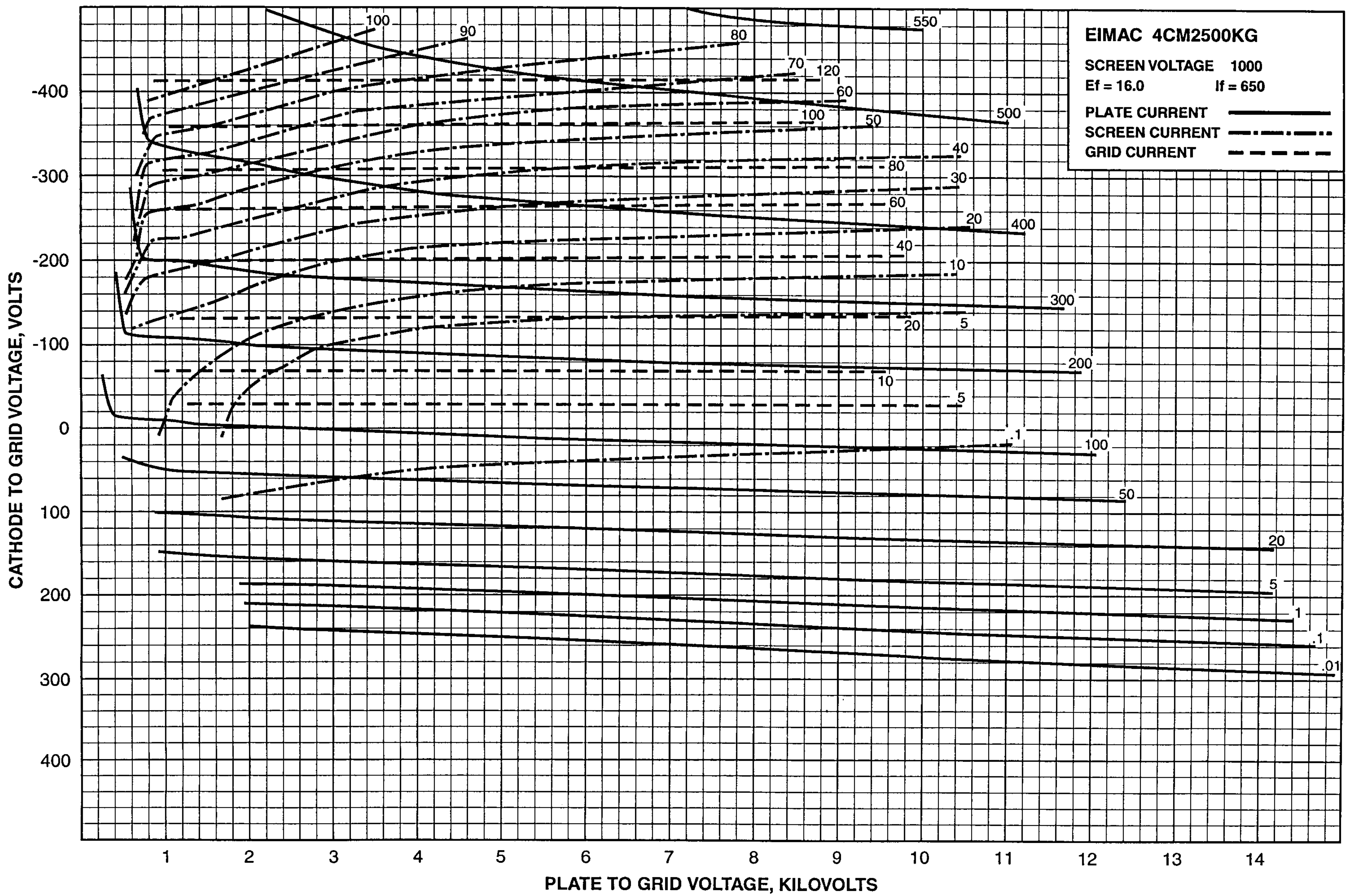
X-RAY RADIATION - High voltage tubes can produce dangerous and possibly fatal x-rays. If shielding is provided equipment should never be operated without all such shielding in place.

Please review the detailed operating hazards sheet enclosed with each tube or request a copy from CPI-EIMAC, Applications Engineering Dept., 301 Industrial Way, San Carlos CA 94070.

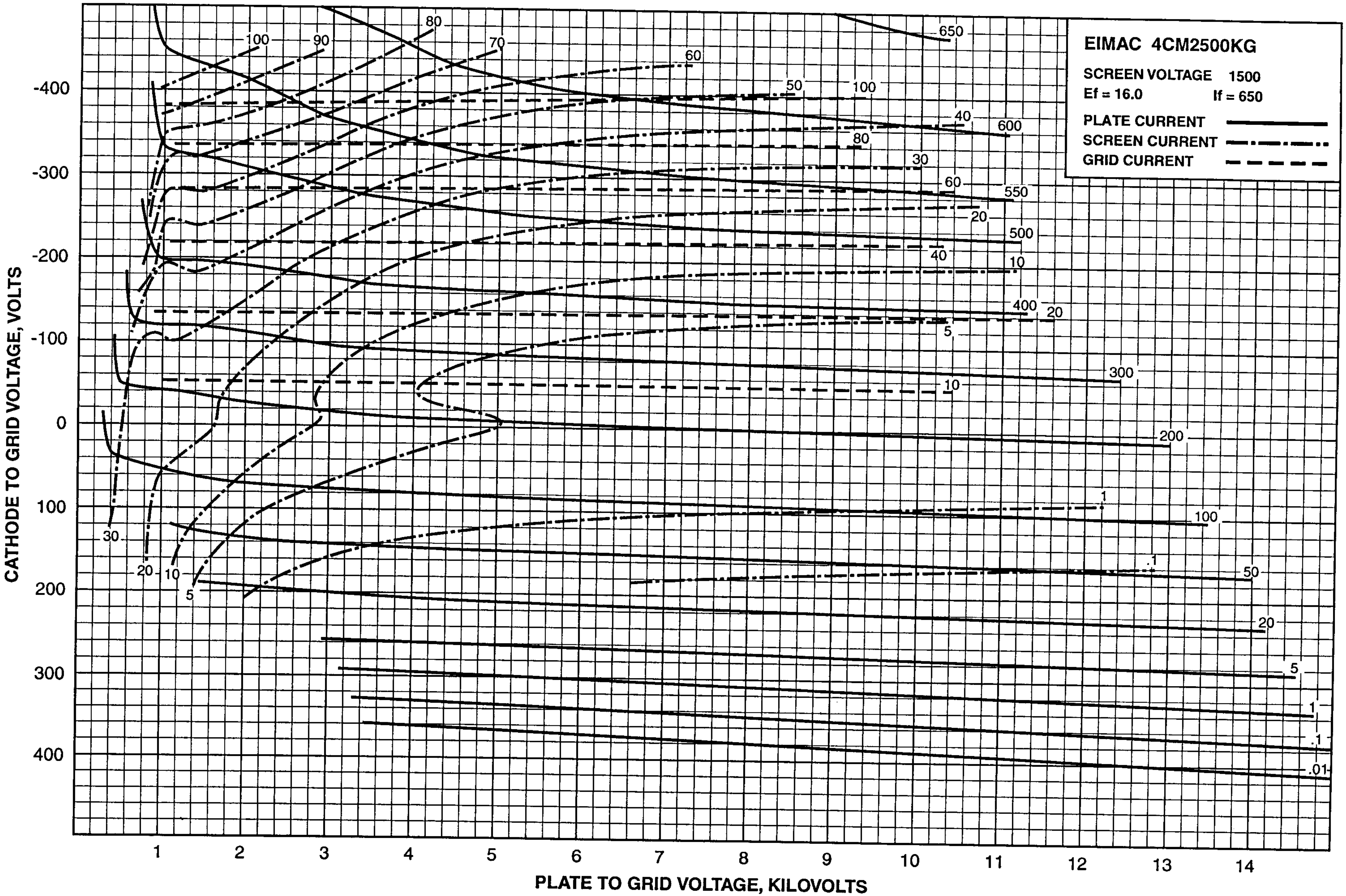
Figure 1 - Tube Vacuum VS Ion Current Reading



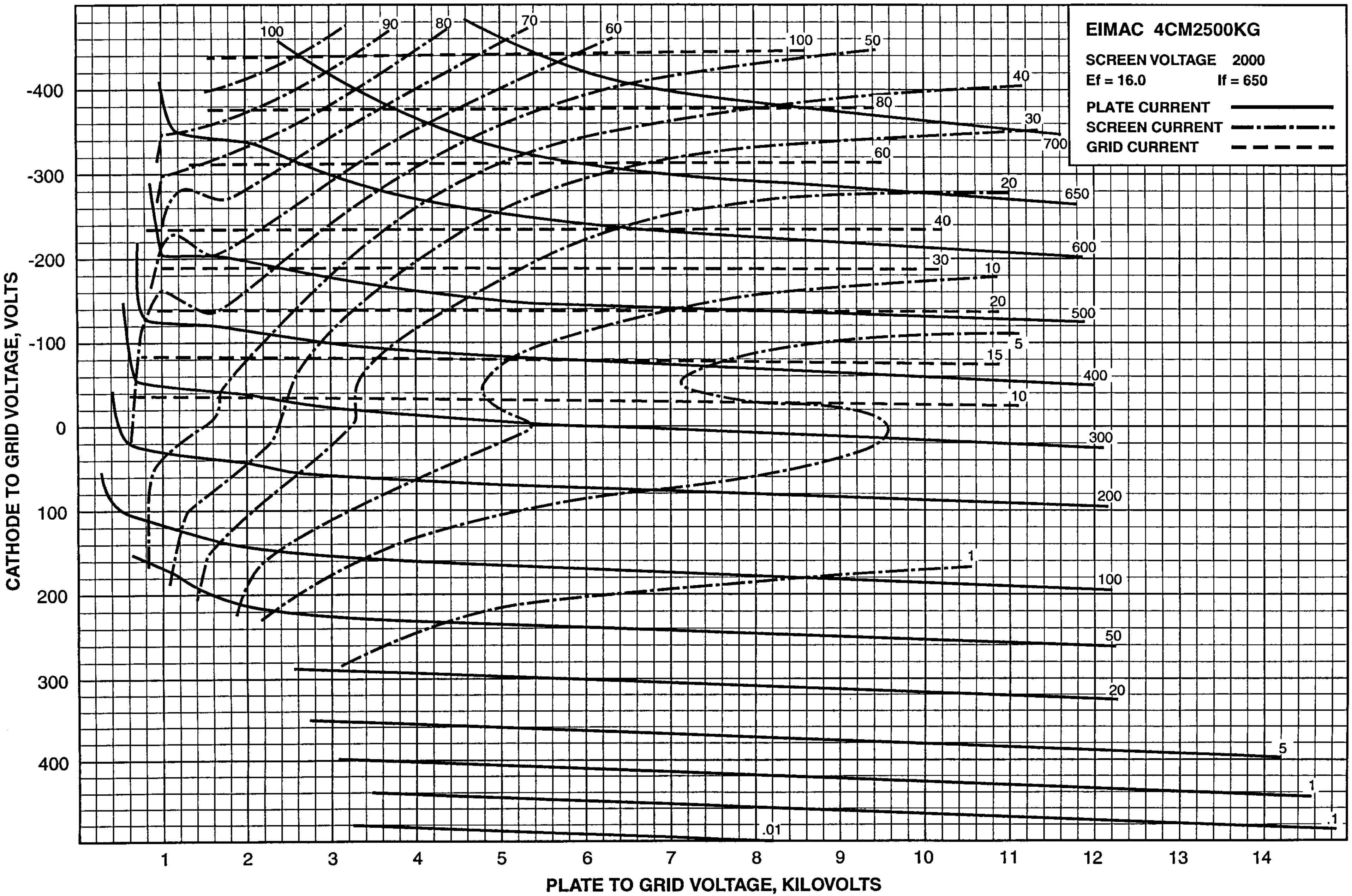
GROUNDED GRID
CONSTANT CURRENT CHARACTERISTICS



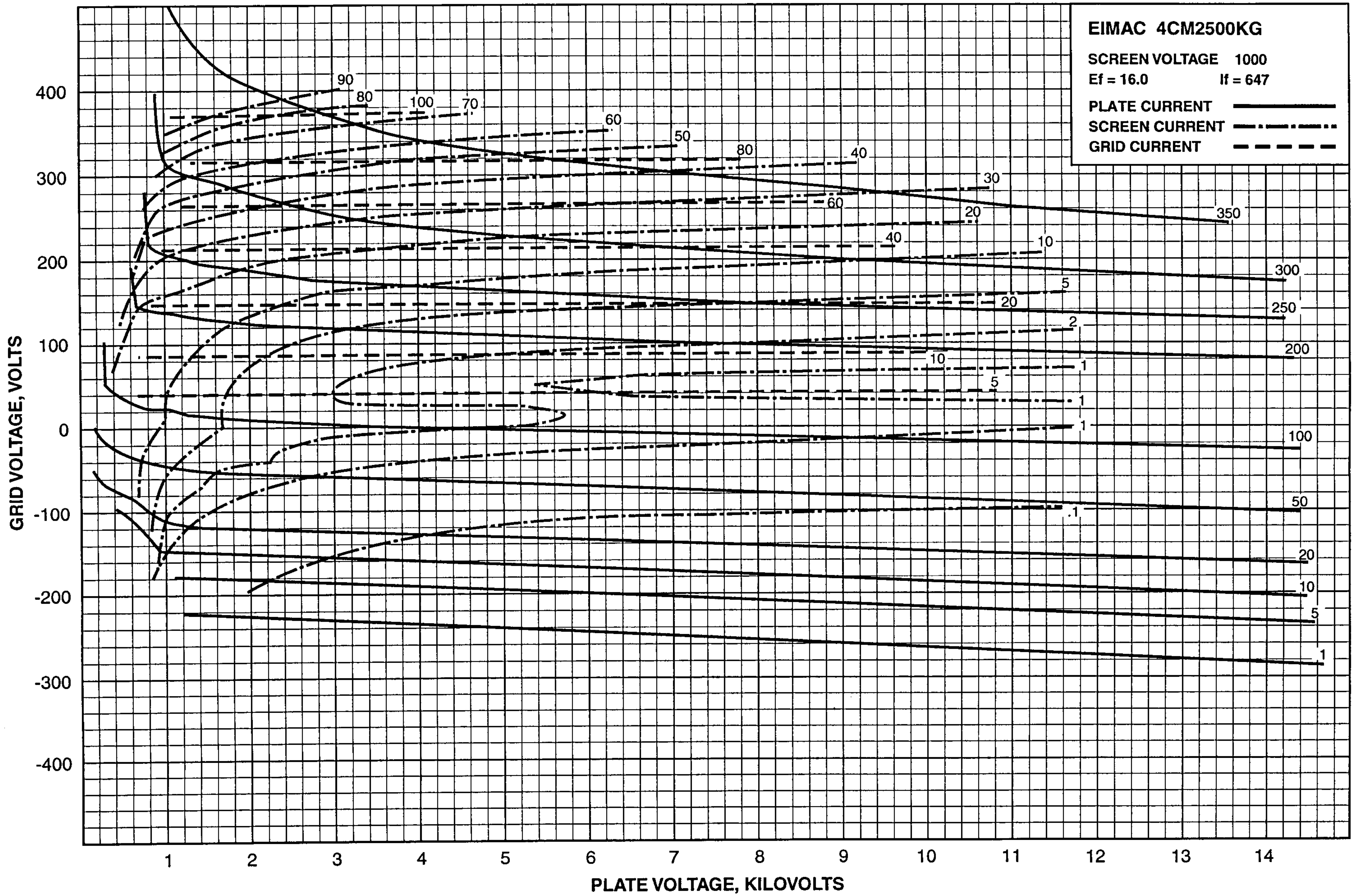
GROUNDED GRID
CONSTANT CURRENT CHARACTERISTICS



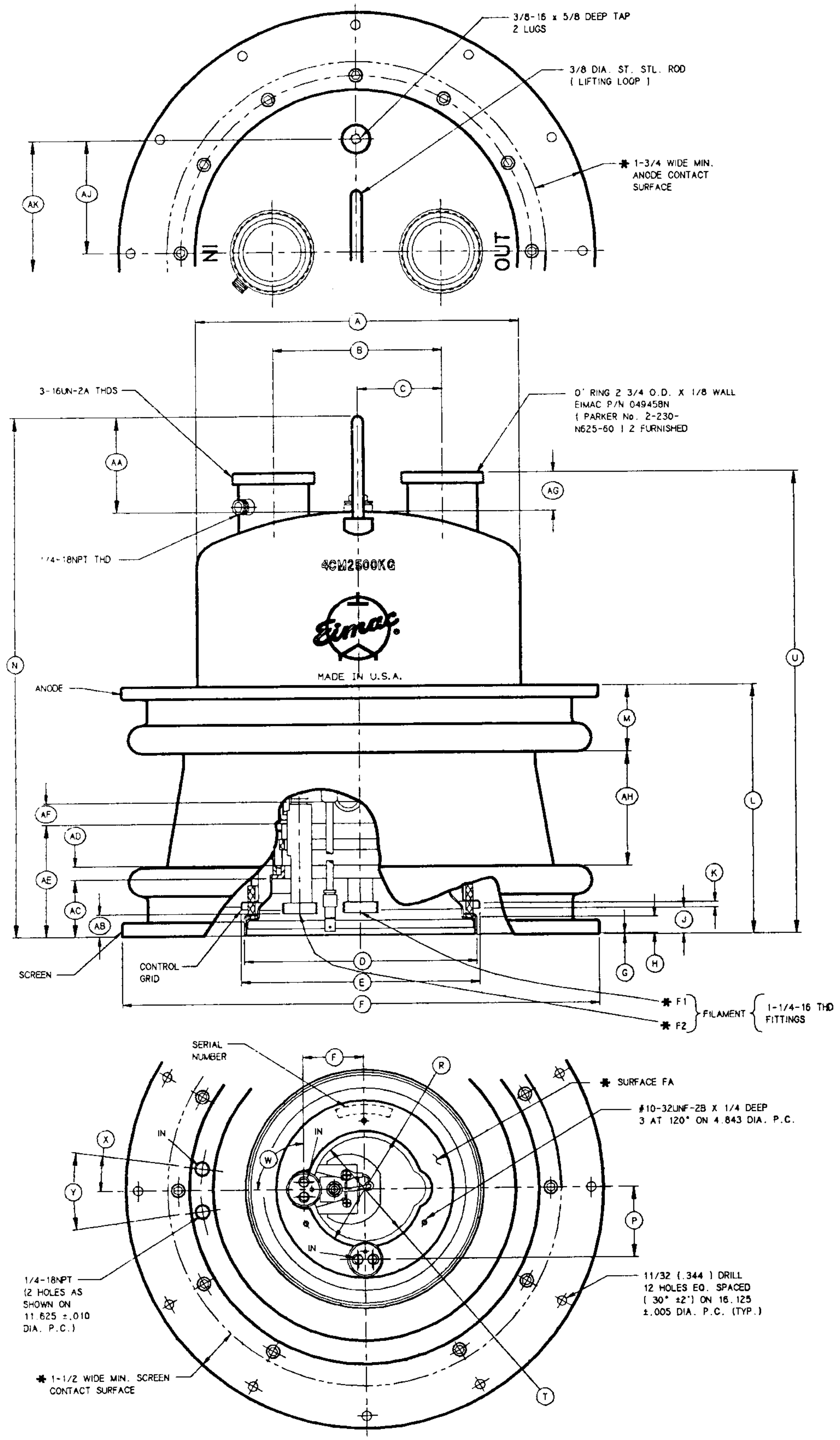
GROUNDED GRID
CONSTANT CURRENT CHARACTERISTICS



GROUNDED CATHODE
CONSTANT CURRENT CHARACTERISTICS



4CM2500KG



DIMENSIONAL DATA						
	INCHES			MILLIMETERS		
DIM.	MIN.	MAX.	REF.	MIN.	MAX.	REF.
A	11.440	11.560		290.58	293.62	
B			6.000			152.40
C			3.000			76.20
D	8.235	8.265		209.17	209.93	
E	8.485	8.525		215.52	216.54	
F	16.970	17.030		431.04	432.56	
G			.025			.635
H	.310			7.87		
J	.900	1.000		22.86	25.40	
K	.180			4.57		
L	8.700	8.900		220.98	226.06	
M			2.375			60.32
N	18.500	18.750		469.90	476.25	
P			2.500			63.50
R	4.113	4.137		104.47	105.08	
T	3.675	3.699		93.34	93.95	
U	16.250	16.500		412.75	419.10	
V			2.156			54.76
W			90°			
X			7.5°			
Y			15°			
AA			3.575			90.80
AB			.720			18.29
AC	1.950	2.100		49.53	53.34	
AD	.450			11.43		
AE	3.560	3.680		90.42	93.47	
AF	.725			18.42		
AG			1.375			34.92
AH			4.093			103.96
AJ			4.000			101.60
AK			8.000			203.20

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301 Industrial Way, San Carlos, CA 94070, USA • Tel: 415-592-1221 • Fax: 415-592-9988

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