8959

HIGH-POWER
WATER-COOLED
TETRODE

TECHNICAL DATA

The EIMAC 8959 is a ceramic/metal high power tetrode for applications requiring tube outputs from 100 to 250 kilowatts. It is ideal for use as a Class C rf amplifier or oscillator, a Class AB rf linear amplifier, or a Class AB push-pull audio amplifier or modulator, as well as a plate and screen modulated Class C rf amplifier.

In pulse modulator service it can deliver a peak output of 4 megawatts.

The tube is characterized by low input and feedback capacitances and low internal lead inductances. Its rugged mesh thoriated tungsten filament provides ample emission for long operating life.

The water-cooled anode dissipates 100 kilowatts when used with an EIMAC SK-2100 series water jacket.

GENERAL CHARACTERISTICS[1]

ELECTRICAL

Filament: Thoriated Tungsten Mesh	
Voltage	15.5 ± 0.75 V
Current, @ 15.5 V	215 A
Direct Interelectrode Capacitances (Grounded Cathode)	
Cin	370 pF
Cout	60 pF
Cgp	1.0 pF
Direct Interelectrode Capacitances (Grounded Grid)	
Cin	175 pF
Cout	60 pF
Cpk	0.35 pF
Frequency of Maximum Rating, CW	108 MHz

1. Characteristics and operating values are based on performance tests. These figures may change without notice as the result of additional data or product refinement. EIMAC Division of Varian should be consulted before using this information for final equipment design.

MECHANICAL

Maximum Overall Dimensions	See Outline Drawing
Net Weight (approximate): Tube Only	38.5 lb; 17.5 kg
Tube and Water Jacket SK-2110	47.0 lb; 21.4 kg
Operating Position	Vertical, base up or down
Anode Cooling (EIMAC SK-2100 series water jacket required, to be ordered separately)	Water
Base Cooling	Forced Air

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Maximum Operating Temperature: Ceramic/Metal Seals and Envelope . . . . . 250°C
Recommended Air-System Socket . . . . . EIMAC SK-2000 Series
Base . . . . . Special Coaxial

RADIO FREQUENCY LINEAR AMPLIFIER

Class AB, Grid Driven

ABSOLUTE MAXIMUM RATINGS

DC PLATE VOLTAGE	20	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC PLATE CURRENT	16	AMPERES
PLATE DISSIPATION	100	KILOWATTS
SCREEN DISSIPATION	1750	WATTS
GRID DISSIPATION	500	WATTS

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

TYPICAL OPERATION
Class AB_1, Grid Driven
Peak Envelope or Modulation Crest Conditions

Plate Voltage	18	kVdc
Screen Voltage	1.5	kVdc
Grid Voltage [1]	-320	Vdc
Zero-Signal Plate Current	4.0	Adc
Single-Tone Plate Current	13.5	Adc
Peak rf Grid Voltage [2]	300	v
Plate Dissipation [2]	75	kW
Plate Output Power [2]	168	kW
Resonant Load Impedance	697	Ω

RADIO FREQUENCY POWER AMPLIFIER OR OSCILLATOR - Class C Telegraphy or FM

(Key-down Conditions)

ABSOLUTE MAXIMUM RATINGS

DC PLATE VOLTAGE	20	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC PLATE CURRENT	16	AMPERES
PLATE DISSIPATION	100	KILOWATTS
SCREEN DISSIPATION	1750	WATTS
GRID DISSIPATION	500	WATTS

1. Approximate value

TYPICAL OPERATION

Plate Voltage	20	kVdc
Screen Voltage	1.5	kVdc
Grid Voltage	-800	Vdc
Plate Current	15.2	Adc
Screen Current [1]	570	mAdc
Grid Current [1]	125	mAdc
Peak rf Grid Voltage [1]	900	v
Driving Power (calculated)	120	W
Plate Dissipation [1]	54	kW
Plate Output Power [1]	220	kW
Resonant Load Impedance	575	Ω

PLATE MODULATED RADIO FREQUENCY AMPLIFIER, GRID DRIVEN

Class C Telephony - Carrier Conditions

ABSOLUTE MAXIMUM RATINGS

DC PLATE VOLTAGE	17.5	KILOVOLTS
DC SCREEN VOLTAGE	2.0	KILOVOLTS
DC PLATE CURRENT	16	AMPERES
PLATE DISSIPATION [2]	67	KILOWATTS
SCREEN DISSIPATION	1750	WATTS
GRID DISSIPATION	500	WATTS

1. Approximate value.
2. Corresponds to 100 kW at 100% sine-wave modulation.

TYPICAL OPERATION

Plate Voltage	15	kVdc
Screen Voltage	750	Vdc
Grid Voltage	-600	Vdc
Plate Current	11.7	Adc
Screen Current [1]	875	mAdc
Grid Current [1]	660	mAdc
Peak Audio Screen Voltage for 100% Modulation	750	v
Peak rf Grid Voltage [1]	800	v
Driving Power (calculated)	530	W
Plate Dissipation [1]	35	kW
Plate Output Power [1]	140	kW
Resonant Load Impedance	620	Ω

AUDIO FREQUENCY POWER AMPLIFIER OR MODULATOR, GRID DRIVEN

Class AB_1, Sinusoidal Wave

ABSOLUTE MAXIMUM RATINGS

DC PLATE VOLTAGE	20	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC PLATE CURRENT	16	AMPERES
PLATE DISSIPATION	100	KILOWATTS
SCREEN DISSIPATION	1750	WATTS
GRID DISSIPATION	500	WATTS

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

TYPICAL OPERATION (2 Tubes)

Plate Voltage	15	kVdc
Screen Voltage	1.5	kVdc
Grid Voltage [1]	-345	Vdc
Zero-Signal Plate Current	6.0	Adc
Max. Signal Plate Current	19.5	Adc
Max. Signal Screen Current [2]	830	mAdc
Peak Audio Grid Voltage/Tube [2]	275	v
Max. Signal Plate Diss./Tube [2]	46	kW
Plate Output Power [2]	200	kW
Load Resistance, plate/plate	1825	Ω

PULSE MODULATOR SERVICE

ABSOLUTE MAXIMUM RATINGS

DC PLATE VOLTAGE	40	KILOVOLTS
DC SCREEN VOLTAGE	2.5	KILOVOLTS
DC GRID VOLTAGE	-2.0	KILOVOLTS
PEAK CATHODE CURRENT	200	AMPERES
PLATE DISSIPATION [1] (DURING PULSE)	1.0	MEGAWATT
PLATE DISSIPATION (AVERAGE)	100	KILOWATTS
SCREEN DISSIPATION (AVERAGE)	1750	WATTS
GRID DISSIPATION (AVERAGE)	500	WATTS
PULSE LENGTH	10	MILLISECONDS

TYPICAL OPERATION

Plate Voltage	40	kVdc
Plate Current, pulse	110	a
Screen Voltage	2.5	kVdc
Screen Current, pulse [2]	12	a
Grid Voltage	-1.2	kVdc
Grid Current, pulse [2]	400	ma
Positive Grid Voltage, pulse [2]	110	v
Duty Factor	6	%
Output Voltage, pulse [2]	37	kv
Input Power, pulse	4.4	Mw
Output Power, pulse [2]	4.1	Mw
Cathode Current, pulse [2]	122	a

1. Power dissipated during rise and fall time neglected.
2. Approximate value.

TYPICAL OPERATION values are obtained by calculations from published characteristic curves. To obtain the specified plate current at the specified bias, screen, and plate voltages, adjustment of the rf grid voltage is assumed. If this procedure is followed, there will be little variation in output power when the tube is replaced, even though there may be some variation in grid and screen currents. The grid and screen currents which occur when the desired plate current is obtained are incidental and vary from tube to tube. These current variations cause no performance degradation providing the circuit maintains the correct voltage in the presence of the current variations. If grid bias is obtained principally by means of a grid resistor, the resistor must be adjustable to produce the required bias voltage when the correct rf grid voltage is applied.

RANGE VALUES FOR EQUIPMENT DESIGN

	Min.	Max.	
Filament Current, at 15.5 volts	200	230	A
Cutoff Bias, at E_b = 25 kVdc, E_{c2} = 1500 Vdc, I_b = 10 mAdc	---	-625	Vdc
Interelectrode Capacitances (measurement without shielded fixture)			
Grounded Cathode Connection:			
Cin	350	390	pF
Cout	55	65	pF
Cgp	---	1.2	pF
Grounded Grid Connection:			
Cin	160	190	pF
Cout	55	65	pF
Cpk	---	0.5	pF

APPLICATION

MOUNTING - The 8959 must be mounted with its major axis vertical. The tube base may be either up or down, at the discretion of the circuit designer.

SOCKETING - An EIMAC SK-2000 Series Socket, or equivalent, is recommended.

ANODE WATER JACKET - An EIMAC SK-2100 or SK-2110 Water Jacket must be used to provide anode cooling. To achieve an anode dissipation of 100 kilowatts, the water jacket must be installed over the tube anode and adequate water flow provided.

COOLING - Anode cooling is accomplished by circulating water through an SK-2100 series Water Jacket. Insufficient water flow will cause the anode temperature to rise to levels which will shorten tube life. Also, if the coolant lines become clogged, enough steam pressure may be generated to rupture the water jacket and destroy the tube. The following table lists the minimum cooling water requirements at various dissipation levels with a maximum inlet water temperature of 50°C.

Anode Dissipation (kW)	Minimum Water Flow (gpm)	Approximate Pressure Drop (psi)
20	5.0	2.8
40	9.0	5.8
60	12.5	9.3
80	16.5	14.2
100	20.0	19.2

Note: Since the filament dissipates about 3500 watts, and the grid-plus-screen can, under some conditions, dissipate another 2250 watts, the table allows for an additional dissipation of 5750 watts.

Outlet water temperature must never exceed 70°C and inlet water pressure should be limited to 80 psi. Direction of water flow is optional.

Tube life can be seriously affected by the condition of the cooling water. If it becomes ionized, copper-oxide deposits 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 20°C should be greater than 50,000 ohms/cm^3, preferably 250,000 ohms/cm^3 or higher. The relative water resistance can be continuously monitored by measuring the leakage current through a short section of the insulating hose, using metal nipples or fittings as electrodes.

Auxiliary forced-air cooling, of the tube base is required to maintain filament- and grid-seal temperatures below 250°C. An air flow of approximately 120 ft^3/min at 50°C maximum and sea level should be directed, through an EIMAC SK-2000 Series Socket or equivalent, toward the filament- and grid-seal areas.

Both anode and base cooling should be applied before or simultaneously with the application of electrode voltages, including the filament. Base cooling should continue for about three minutes after the removal of electrode voltages to allow the tube to cool properly.

FILAMENT OPERATION - At rated filament voltage, the peak emission of the 8959 is many times greater than the amount needed for communication service. Reducing the filament voltage decreases the filament temperature. A small decrease in filament temperature substantially increases filament life. The correct value of filament-voltage should be determined for the particular applications. First, gradually reduce the filament voltage to the point where there is a noticeable reduction in plate current or power output, or an increase in distortion. Then increase the voltage several tenths of a volt above the value where performance degradation occurred; this is the proper operating voltage. Filament voltage should always be measured at the tube base or socket using an rms responding meter. The above procedure should be performed periodically to assure optimum tube life.

GRID OPERATION - The maximum control-grid dissipation is 500 watts, determined approximately by the product of grid current and peak positive grid voltage.

Under some operating conditions, the control grid may exhibit a negative-resistance characteristic. This may occur when, with high screen-grid voltage, increasing the drive voltage decreases the grid current. As a result, large values of instantaneous negative grid current can be produced, causing the amplifier to become regenerative. Because this may happen, the driver stage must be designed to tolerate this condition. One technique is to swamp the driver so that the change in load, due to secondary grid emission, is a small percentage of the total driver load.

SCREEN OPERATION - The maximum screen-grid dissipation is 1750 watts. With no ac applied to the screen, dissipation is simply the product of dc screen voltage and dc screen current. With screen modulation, dissipation is dependent on rms screen voltage and rms screen current.

Plate voltage, plate loading, or bias voltage must never be removed while filament and screen voltages are present, since the screen dissipation rating will be exceeded. Suitable protective circuitry should be provided.

The 8959 may exhibit reverse screen current to a greater or lesser degree depending on operating conditions. The screen supply voltage must be maintained constant for any values of negative and positive screen current which may be encountered. Dangerously high plate current may flow if the screen power supply exhibits a rising voltage characteristic with negative screen current. Stabilization may be accomplished with a bleeder resistor connected from screen to cathode, or an electron-tube regulator circuit may be employed in the screen supply. A bleeder resistor must be used if a series electron-tube regulator is employed.

PLATE DISSIPATION - The rated plate dissipation of 100 kilowatts, attainable with water cooling, provides a large margin of safety in most applications. This rating may be exceeded briefly during tuning. When the 8959 is used as a plate-modulated rf amplifier, plate dissipation under carrier conditions should be limited to 67 kilowatts.

FAULT PROTECTION - In addition to the normal plate-overcurrent interlock, screen-current interlock, and coolant-flow interlock, it is good practice to protect the tube from internal damage caused by an internal plate arc which may occur at high plate voltages.

A protective resistance of 5 to 25 ohms should always be connected in series with each tube anode, to absorb power-supply stored energy if a plate arc should occur. An electronic crowbar, which will discharge power-supply capacitors in a few microseconds after the start of a plate arc, is recommended.

OPERATING HAZARDS

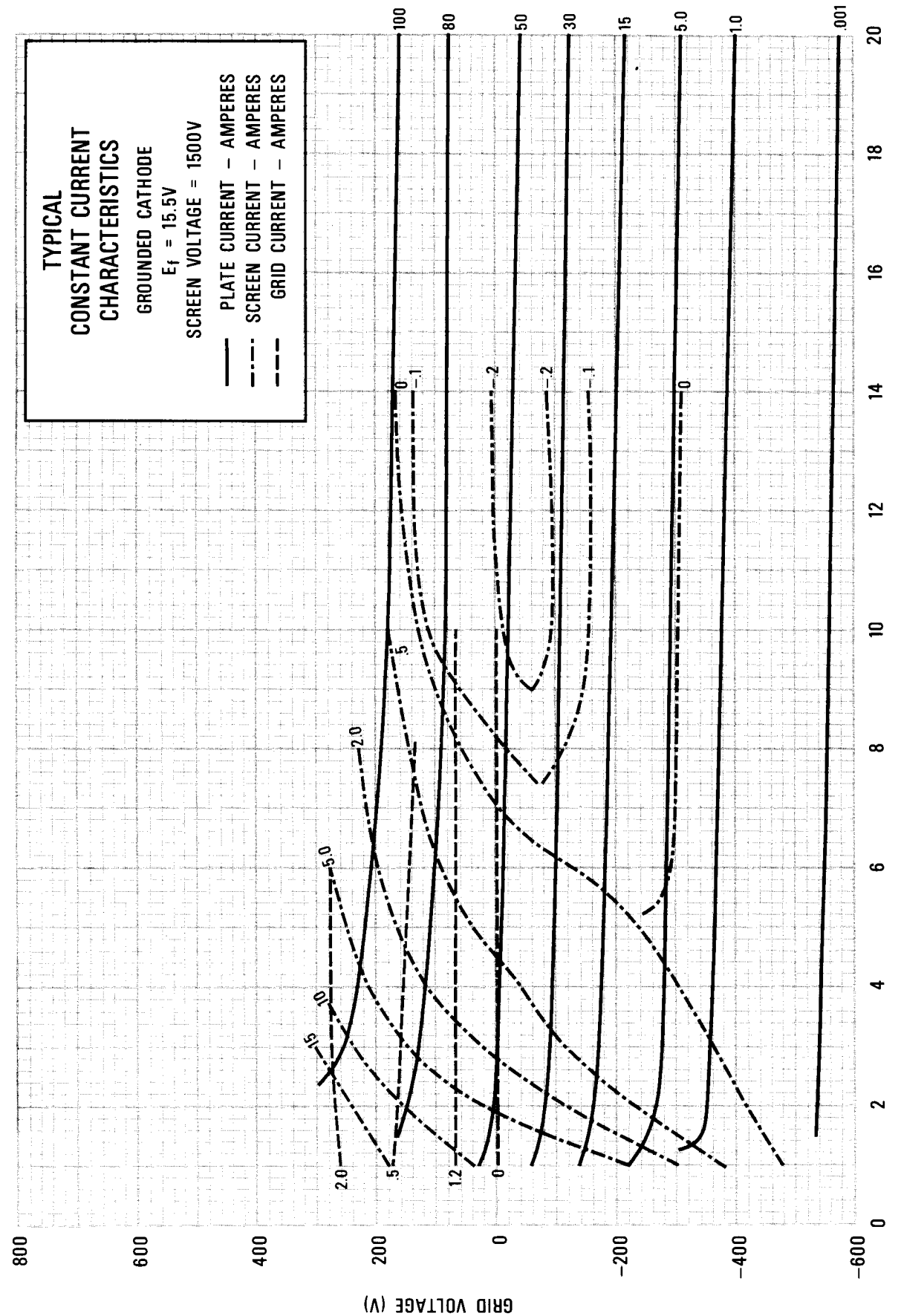
Read the following and take all necessary precautions to safeguard personnel. Safe operating conditions are the responsibility of the equipment designer and the user.

HIGH VOLTAGE - This tube operates at voltages which can be deadly. Equipment must be designed so personnel cannot come in contact with operating voltages. Enclose high-voltage circuits and terminals and provide fail-safe interlocking switch circuits to open the primary circuits of the power supply and to discharge high-voltage condensers whenever access into the enclosure is required.

X-RAY RADIATION - The EIMAC 8959, operating at its rated voltages and currents, is a potential X-ray hazard. Moreover, the X-ray radiation level can increase significantly with aging and gradual deterioration, due to changes in leakage paths or emission characteristics as they are affected by high voltage. Only limited shielding is afforded by the tube envelope. Additional X-ray shielding must be provided on all sides of the tube to provide adequate protection to operating personnel throughout the tube's life. When this tube is used as a pulse modulator, shielding of the pulse transformer may also be necessary. X-ray caution signs or labels must be permanently attached to equipment using this tube directing operating personnel never to operate this device without X-ray shielding in place.

RADIO FREQUENCY RADIATION - Exposure of the human body to rf radiation becomes increasingly more hazardous as the power level and/or frequency are increased. Exposure to high-power rf radiation must be strictly prevented at any frequency.

Equipment must be designed to fully safeguard all personnel from these hazards. Labels and caution notices must be provided on equipment and in manuals clearly warning of these hazards.


TYPICAL
CONSTANT CURRENT
CHARACTERISTICS
GROUNDED CATHODE
E_f = 15.5V
SCREEN VOLTAGE = 1500V
PLATE CURRENT – AMPERES
SCREEN CURRENT – AMPERES
GRID CURRENT – AMPERES
GRID VOLTAGE (V)
PLATE VOLTAGE (kV)
800
600
400
200
0
−200
−400
−600
0
2
4
6
8
10
12
14
16
18
20
100
80
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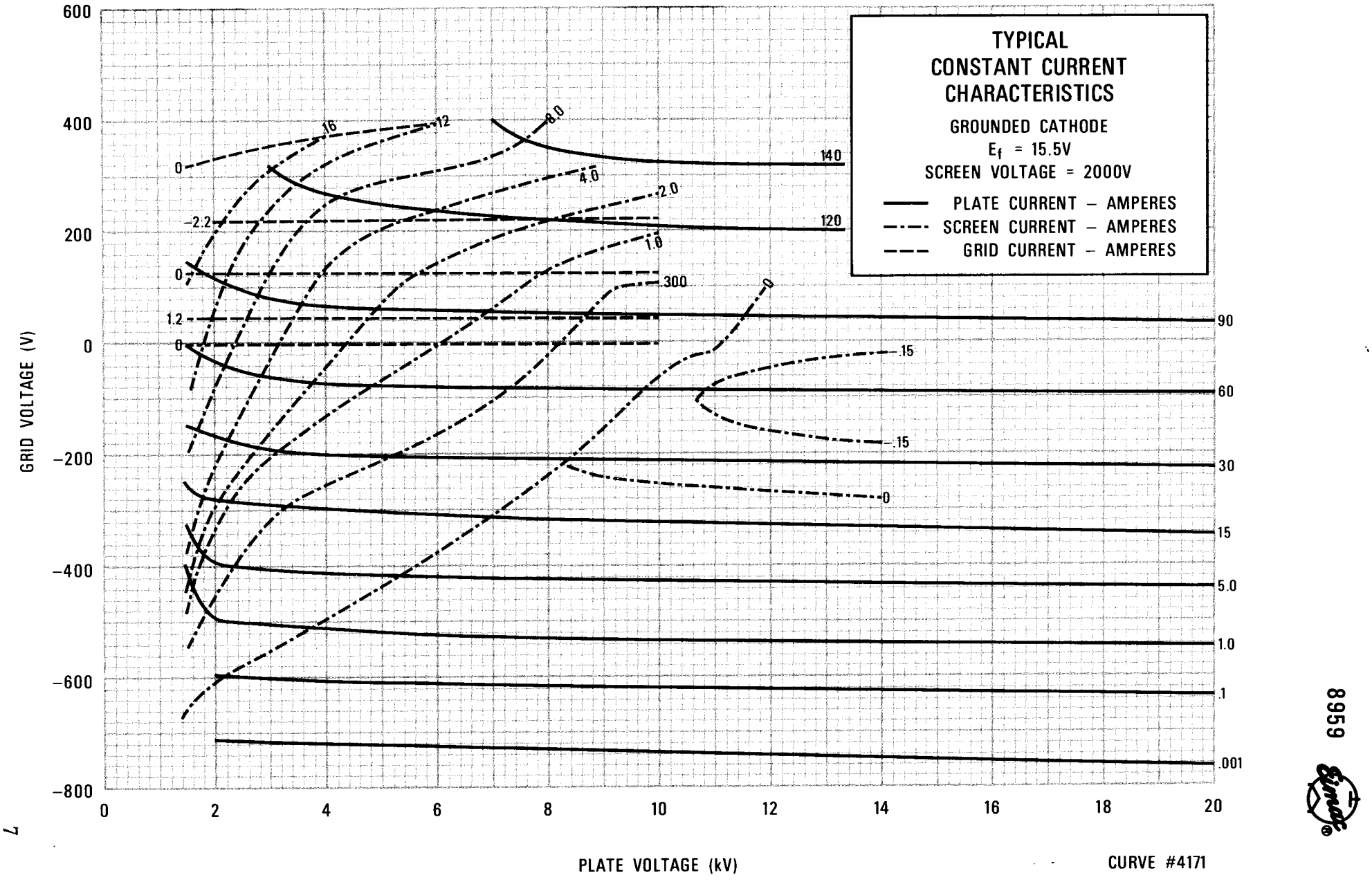
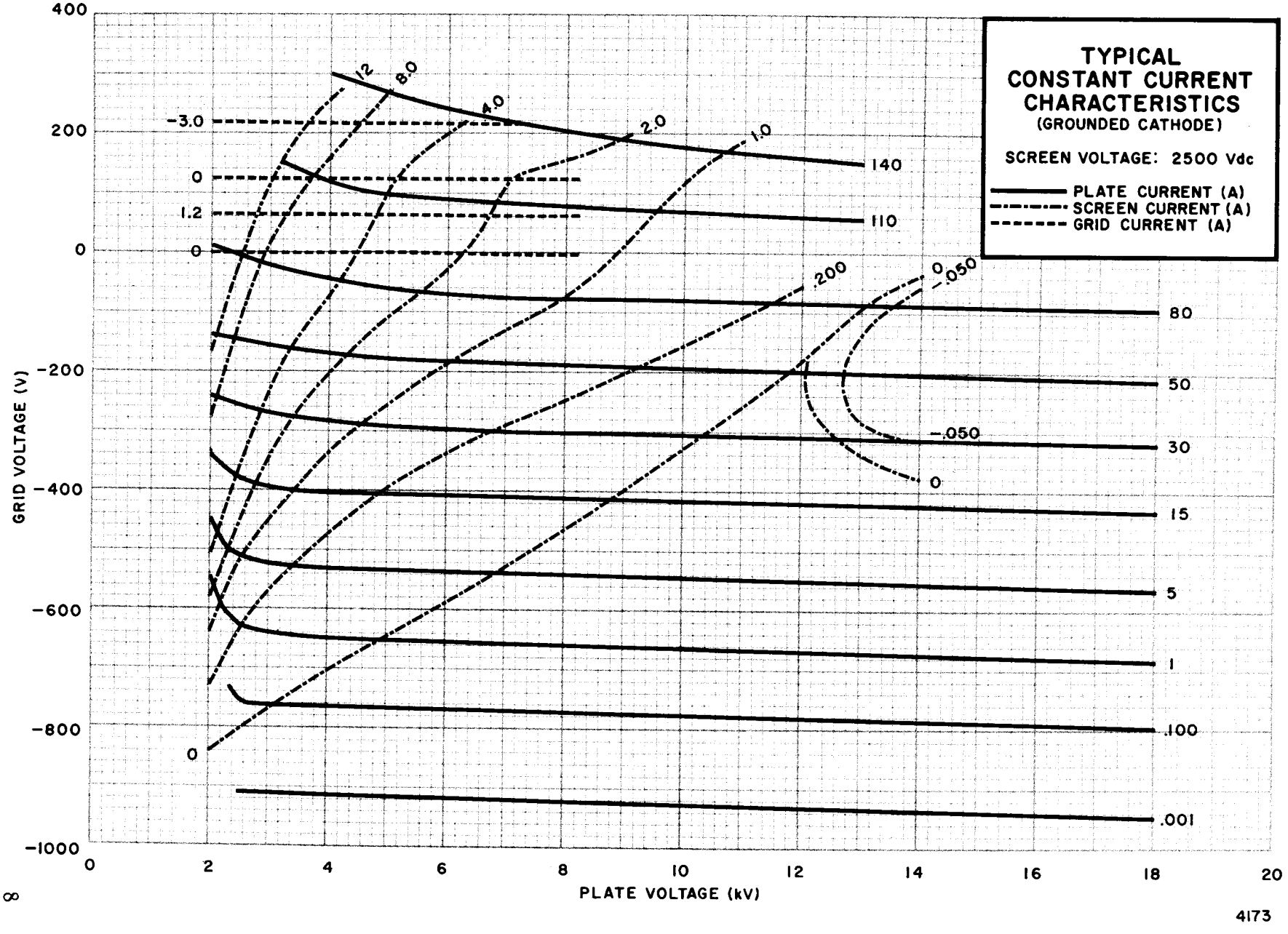
−10
−15

CURVE #4169



CURVE #4171

8959


TYPICAL
CONSTANT CURRENT
CHARACTERISTICS
(GROUNDED CATHODE)
SCREEN VOLTAGE: 2500 Vdc
PLATE CURRENT (A)
SCREEN CURRENT (A)
GRID CURRENT (A)
GRID VOLTAGE (V)
PLATE VOLTAGE (kV)
400
200
0
-200
-400
-600
-800
-1000
0
2
4
6
8
10
12
14
16
18
20
12
8.0
4.0
2.0
1.0
-3.0
0
1.2
0
140
110
80
50
30
15
5
1
.100
.001
.200
0
-.050
-.050
0
0
4173

8959