# 4CW100,000E

## TECHNICAL DATA

HIGH-POWER WATER-COOLED TETRODE

The 4CW100,000E 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 af 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 the EIMAC SK-2100 water jacket.

4CW100,000E without SK-2100 Water Jacket

## GENERAL CHARACTERISTICS[1]

### ELECTRICAL

Filament: Thoriated Tungsten

| | |
|---|---|
| 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 upon 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

| | |
|---|---|
| Dimensions | See Outline Drawing |
| Net Weight | |
| Tube Only | 38.5 lb; 17.5 kg |
| Tube and Water Jacket | 47.0 lb; 21.4 kg |
| Operating Position | Vertical, base up or down |
| Anode Cooling | Water |
| Base Cooling | Forced Air |



varian, **EIMAC** division/301 industrial way/san carlos/california 94070

| | |
|---|---|
| Maximum Operating Temperature | |
| Ceramic/Metal Seals and Envelope | 250°C |
| Anode Water Jacket, required | EIMAC SK-2100 |
| Air System Socket, recommended | EIMAC SK-2011A |
| Base | Special |

**RADIO FREQUENCY LINEAR AMPLIFIER,**
Class AB

ABSOLUTE MAXIMUM RATINGS

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

1. Adjust to give specified zero-signal plate current.

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 Adc |
| Signal-Tone Plate Current | 13.5 Adc |
| Peak rf Grid Voltage, (approx.) | 300 v |
| Plate Dissipation | 75 kW |
| Plate Output Power | 168 kW |
| Resonant Load Impedance | 697 Ω |

**RADIO FREQUENCY POWER AMPLIFIER OR OSCILLATOR**
Class C Telegraphy or FM
(Key-Down Conditions)

ABSOLUTE MAXIMUM RATINGS

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

TYPICAL OPERATION

| | |
|---|---|
| Plate Voltage | 20 kVdc |
| Screen Voltage | 1.5 kVdc |
| Grid Voltage | -800 Vdc |
| Plate Current | 15.2 Adc |
| Screen Current, (approx.) | 567 mAdc |
| Grid Current, (approx.) | 125 mAdc |
| Peak rf Grid Voltage, (approx.) | 900 v |
| Driving Power, calculated, (approx.) | 120 W |
| Plate Dissipation | 54 kW |
| Plate Output Power | 220 kW |
| Resonant Load Impedance | 575 Ω |

**PLATE MODULATED RADIO FREQUENCY AMPLIFIER GRID DRIVEN**
Class C Telephony (Carrier Conditions)

ABSOLUTE MAXIMUM RATINGS

| | | |
|---|---|---|
| PLATE VOLTAGE | 17.5 | KILOVOLTS |
| SCREEN VOLTAGE | 2.0 | KILOVOLTS |
| PLATE CURRENT | 16 | AMPERES |
| PLATE DISSIPATION[1] | 67 | KILOWATTS |
| SCREEN DISSIPATION[2] | 1750 | WATTS |
| GRID DISSIPATION[2] | 500 | WATTS |

1. Corresponds to 100 kW at 100% sine-wave modulation.
2. Average value, with or without modulation.

TYPICAL OPERATION

| | |
|---|---|
| Plate Voltage | 15 kVdc |
| Screen Voltage | 750 Vdc |
| Grid Voltage | -600 Vdc |
| Plate Current | 11.7 Adc |
| Screen Current, (approx.) | 875 mAdc |
| Grid Current, (approx.) | 660 mAdc |
| Peak af Screen Voltage, 100% mod., (approx.) | 750 v |
| Peak rf Grid Voltage, (approx.) | 800 v |
| Driving Power, (calculated) | 530 W |
| Plate Dissipation | 35 kW |
| Plate Output Power | 140 kW |
| Resonant Load Impedance | 620 Ω |

**AUDIO FREQUENCY POWER AMPLIFIER OR MODULATOR GRID DRIVEN**
Class AB 1, (Sinusoidal Wave)

ABSOLUTE MAXIMUM RATINGS (Per Tube)

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

1. Adjust to give specified zero-signal plate current.

TYPICAL OPERATION (Two Tubes)

| | |
|---|---|
| Plate Voltage | 15 kVdc |
| Screen Voltage | 1.5 kVdc |
| Grid Voltage, (approx.)[1] | -345 Vdc |
| Zero-Signal Plate Current | 6 Adc |
| Maximum-Signal Plate Current | 19.5 Adc |
| Max. Signal Screen Current, (approx.) | 830 mAdc |
| Peak af Grid Voltage, (per tube) | 275 v |
| Maximum-Signal Plate Dissipation per tube | 46 kW |
| Plate Output Power | 200 kW |
| Load Resistance, (plate to plate) | 1825 Ω |

**PULSE MODULATOR SERVICE**

ABSOLUTE MAXIMUM RATINGS

| | | |
|---|---|---|
| PLATE VOLTAGE | 40 | kVdc |
| SCREEN VOLTAGE | 2.5 | kVdc |
| GRID VOLTAGE | -2.0 | kVdc |
| PEAK CATHODE CURRENT | 200 | a |
| PLATE DISSIPATION (during the pulse[1]) | 1.0 | MW |
| PLATE DISSIPATION, (average) | 100 | kW |
| SCREEN DISSIPATION, (average) | 1750 | W |
| GRID DISSIPATION, (average) | 500 | W |
| PULSE LENGTH | 10 | ms |

TYPICAL OPERATION

| | | |
|---|---|---|
| Plate Voltage | 40 | kVdc |
| Plate Current, (pulse) | 110 | a |
| Screen Voltage | 2.5 | kVdc |
| Screen Current, (pulse), (approx.) | 12 | a |
| Grid Voltage | -1.2 | kVdc |
| Grid Current, (pulse), (approx.) | 400 | ma |
| Positive Grid Voltage, (pulse) | 110 | v |
| Duty | 6 | % |
| Output Voltage, (pulse) | 37 | kv |
| Input Power, (pulse) | 4.4 | Mw |
| Output Power, (pulse) | 4.1 | Mw |
| Cathode Current, (pulse), (approx.) | 122 | a |

1. Power dissipated during rise and fall time neglected.

NOTE: 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 @ 15.5 volts | 200 | 230 | A |
| Cutoff Bias, at Eb = 25 kVdc, Ec2 = 1500 Vdc, Ib = 10 mAdc | --- | -625 | Vdc |
| Interelectrode Capacitances (grounded cathode) | | | |
| Cin | 350 | 390 | pF |
| Cout | 55 | 65 | pF |
| Cgp | --- | 1.2 | pF |
| Interelectrode Capacitances (grounded grid) | | | |
| Cin | 160 | 190 | pF |
| Cout | 55 | 65 | pF |
| Cpk | --- | 0.5 | pF |

## APPLICATION

### MECHANICAL

*MOUNTING* - The 4CW100,000E 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-2100 series Socket, or equivalent, is recommended.

*ANODE WATER JACKET* - The EIMAC SK-2100 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 the SK-2100 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 |

System pressure should be limited to 80 psi. High-purity water must be used to minimize power loss, corrosion of metal fittings, and loss of anode dissipation capability. Water resistivity must be maintained at 1 megohm/$cm^3$ or better for long term operation.

EIMAC Application Bulletin #16 titled "WATER PURITY REQUIREMENTS IN LIQUID COOLING SYSTEMS" is available on request, and should be consulted for details on maintenance of water quality standards and use of a water purification loop in the installation. Since the anode is normally at high potential to ground, water connections to the anode are made through insulating tubing, with long enough sections that column resistance is above 4 megohms per 1000 plate supply volts, or 10 megohms total, whichever is less.

Auxillary forced-air cooling, of the tube base is required to maintain filament- and grid-seal temperatures below 250°C. An air flow of approximately 100 $ft^3$/min at 50°C maximum and sea level should be directed, through an EIMAC SK-2011A 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.

## ELECTRICAL

*FILAMENT OPERATION* - During turn-on inrush current should be limited to twice normal (nominal) current. At rated filament voltage, the peak emission of a 4CW100,000E 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 4CW100,000E 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 4CW100,000E 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.

EIMAC Application Bulletin #17 titled "FAULT PROTECTION" is available on request and contains considerable detail on the subject, including a suggested test procedure to show the adequacy of the protection system in use.

Properly rated spark gaps must also be located between the screen grid and cathode and between the control grid and cathode to meet over-voltage protection criteria. A series resistance of 10 to 50 ohms is recommended in the screen and control grid power supply leads.

*X-RADIATION* - 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 rated voltage and current, 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 15 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.

*HIGH VOLTAGE* - Normal operating voltages used with these tubes 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.

*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* - If it is desired to operate this tube under conditions widely different from those listed here, write to Power Grid Tube Division, EIMAC Division of Varian, 301 Industrial Way, San Carlos, California, 94070, For information and recommendations.

## 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.

The operation of power tubes involves one or more of the following hazards, any one of which, in the absence of safe operating practices and precautions, could result in serious harm to personnel:

a. HIGH VOLTAGE - Normal operating voltages can be deadly.

b. 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 and can cause serious bodily and eye injuries. CARDIAC PACEMAKERS MAY BE AFFECTED.

c. X-RAY RADIATION - High voltage tubes can produce dangerous and possibly fatal x-rays.

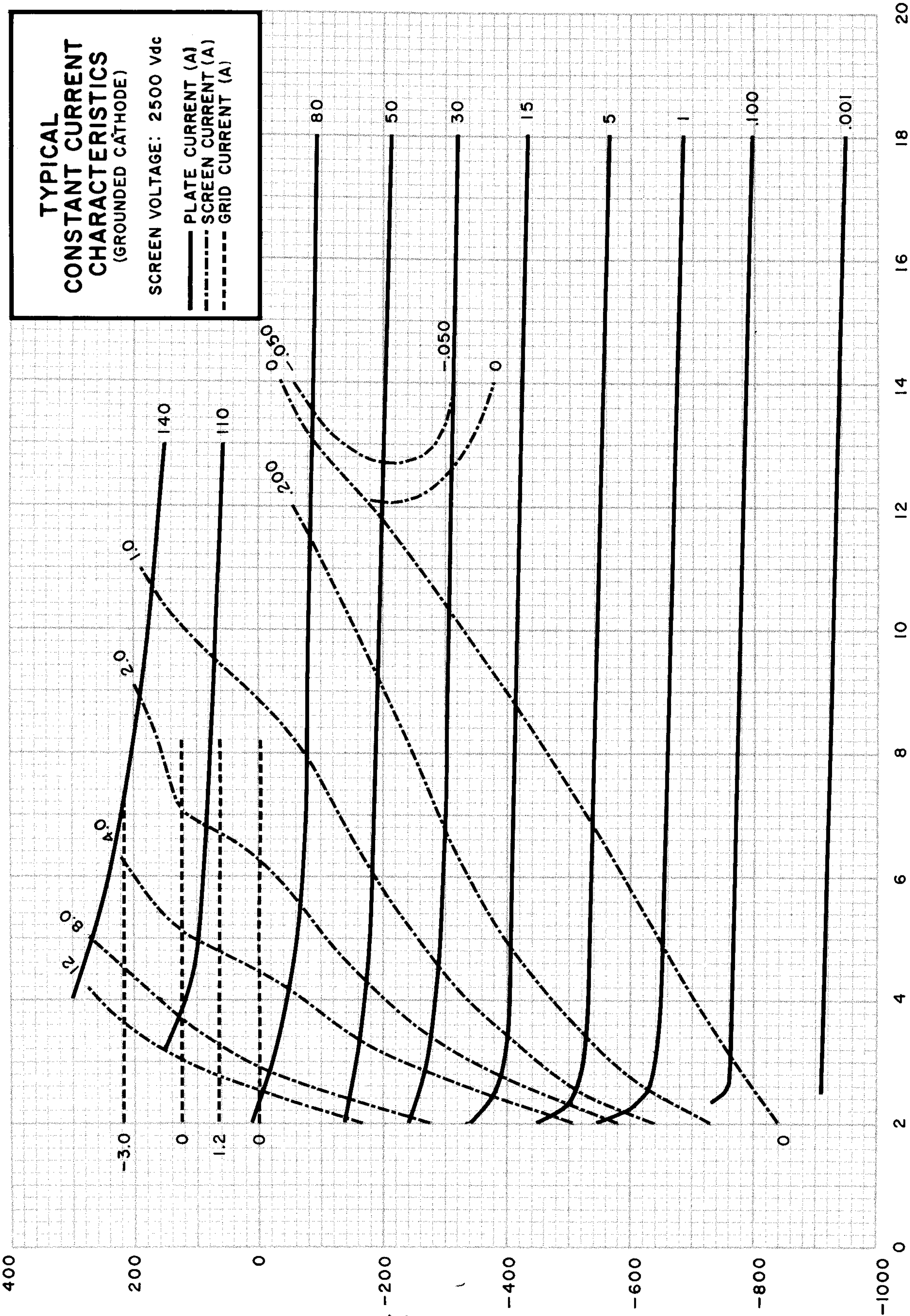
d. BERYLLIUM OXIDE POISONING - Dust or fumes from BeO ceramics used as thermal links with some conduction-cooled power tubes are highly toxic and can cause serious injury or death.

e. GLASS EXPLOSION - Many electron tubes have glass envelopes. Breaking the glass can cause an implosion, which will result in an explosive scattering of glass particles. Handle glass tubes carefully.

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

g. HOT SURFACES - Surfaces of air-cooled radiators and other parts of tubes can reach temperatures of several hundred degrees centigrade and cause serious burns if touched.

Please review the detailed operating hazards sheet enclosed with each tube or request a copy from the address shown below: Power Grid Tube Division, EIMAC Division of Varian, 301 Industrial Way, San Carlos, California 94070.



TYPICAL
CONSTANT CURRENT
CHARACTERISTICS
(GROUNDED CATHODE)
SCREEN VOLTAGE: 2500 Vdc
PLATE CURRENT (A)
SCREEN CURRENT (A)
GRID CURRENT (A)
PLATE VOLTAGE (kV)
GRID VOLTAGE (V)
0
2
4
6
8
10
12
14
16
18
20
400
200
0
-200
-400
-600
-800
-1000
140
110
80
50
30
15
5
1
.100
.001
12
8.0
4.0
2.0
1.0
0.050
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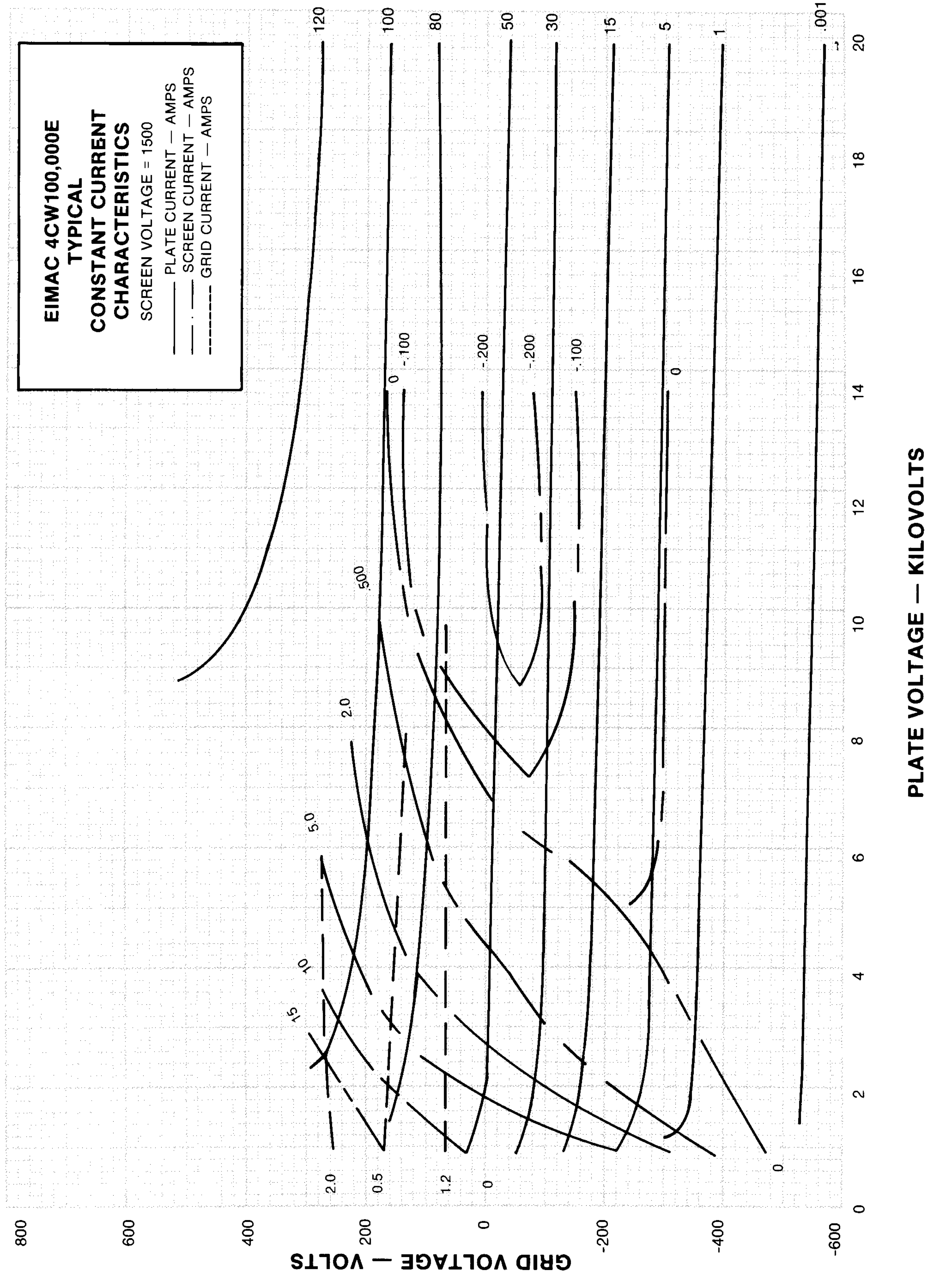
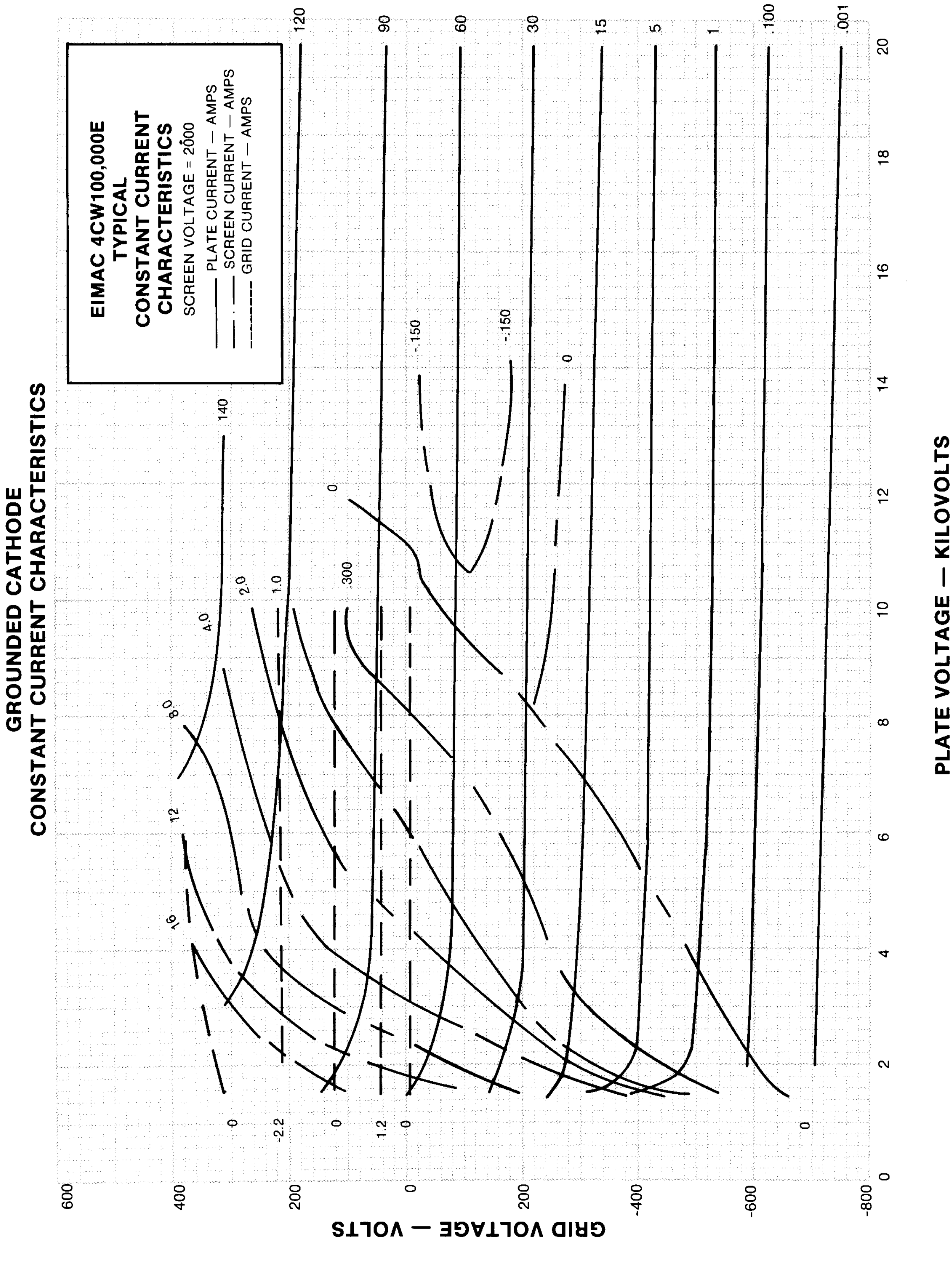
0
-3.0
0
1.2
0
0
200

## GROUNDED CATHODE
## CONSTANT CURRENT CHARACTERISTICS




GROUNDED CATHODE
CONSTANT CURRENT CHARACTERISTICS
EIMAC 4CW100,000E
TYPICAL
CONSTANT CURRENT
CHARACTERISTICS
SCREEN VOLTAGE = 2000
PLATE CURRENT — AMPS
SCREEN CURRENT — AMPS
GRID CURRENT — AMPS
PLATE VOLTAGE — KILOVOLTS
GRID VOLTAGE — VOLTS
120
90
60
30
15
5
1
.100
.001
140
4.0
2.0
1.0
8.0
12
16
.300
-.150
-.150
0
-2.2
1.2
600
400
200
0
-200
-400
-600
-800
0
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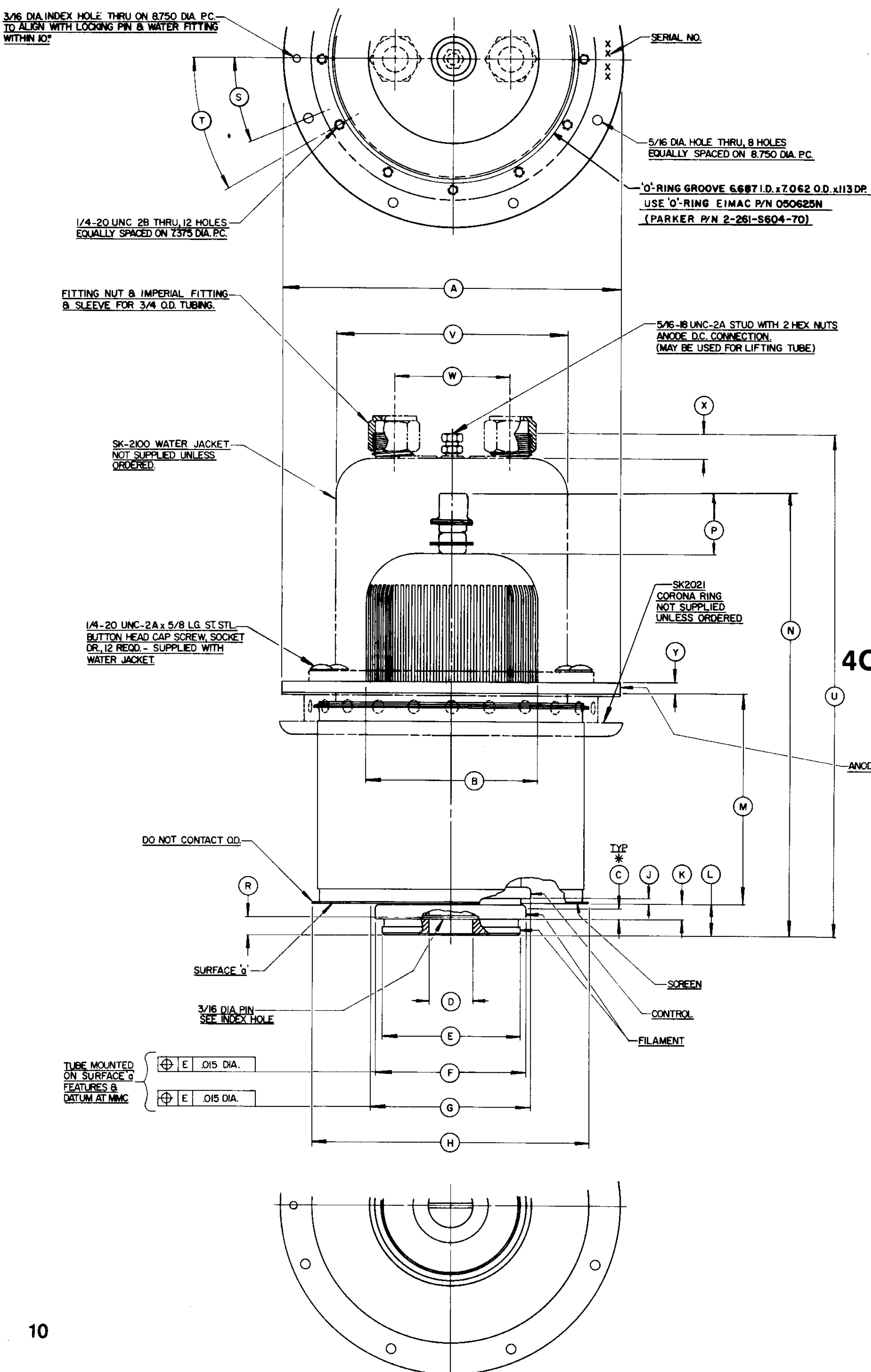
18
20




# 4CW100,000E

| DIMENSIONAL DATA | | | | | | |
|---|---|---|---|---|---|---|
| | INCHES | | | MILLIMETERS | | |
| DIM. | MIN. | MAX. | REF. | MIN. | MAX. | REF. |
| A | 9.468 | 9.531 | | 240.49 | 242.09 | |
| B | | | 5.000 | | | 127.00 |
| C | .125 | | | 3.17 | | |
| D | 1.250 | 1.280 | | 31.75 | 32.51 | |
| E | 3.865 | 3.885 | | 98.17 | 98.68 | |
| F | 4.240 | 4.260 | | 107.70 | 108.20 | |
| G | 4.490 | 4.510 | | 114.05 | 114.55 | |
| H | | | 7.750 | | | 196.85 |
| J | .069 | .149 | | 1.75 | 3.78 | |
| K | .382 | .462 | | 9.70 | 11.73 | |
| L | .797 | .922 | | 20.24 | 23.42 | |
| M | 5.875 | 6.000 | | 149.22 | 152.40 | |
| N | | | 12.659 | | | 321.54 |
| P | | | 1.327 | | | 33.71 |
| R | .469 | .531 | | 11.91 | 13.49 | |
| S | | | 22 1/2° | | | 22 1/2° |
| T | | | 30° | | | 30° |
| U | 13.750 | 14.250 | | 349.25 | 361.95 | |
| V | 6.437 | 6.562 | | 163.50 | 166.67 | |
| W | 3.187 | 3.313 | | 80.95 | 84.15 | |
| X | | | .562 | | | 14.27 |
| Y | | | .312 | | | 7.92 |

NOTES:

1. REF. DIMENSIONS ARE FOR INFO. ONLY & ARE NOT REQUIRED FOR INSPECTION PURPOSES.
2. (*) MIN. CONTACT SURFACE.