ISSUED 9-67

ML-6696
ML-6697

General Purpose Triodes
80 kW CW

MACHLETT

DESCRIPTION

The ML-6696 and ML-6697 are general-purpose triodes suitable for industrial heating and AM broadcasting. These tubes feature rugged coaxial mounting structures providing high-dissipation, low inductance rf electrode terminals. The cathode of each type consists of sturdy, self-supporting, stress-free, thoriated-tungsten filaments.

The ML-6696 has a water-cooled, heavy-wall anode capable of dissipating 60 kW. The ML-6697 has a forced-air-cooled, heavy-wall anode with high-efficiency disc fins capable of dissipating 35 kW.

These tubes will operate with plate voltages up to 16 kV in CW operation. Maximum ratings apply at frequencies up to 30 MHz. Useful power output can be obtained at frequencies up to 70 MHz with reduced ratings.

GENERAL CHARACTERISTICS

Electrical

Filament Voltage	13.0	Volts
Filament Current	205	Amps
Filament Starting Current, maximum	800	Amps
Filament Cold Resistance	0.0073	Ohm
Amplification Factor	20	
Interelectrode Capacitances		
Grid-Plate	55	pf
Grid-Filament	76	pf
Plate-Filament	2.7	pf

Mechanical

Mounting Position	Vertical, anode down	
Type of Cooling — ML-6696	Water and forced-air†	
Water flow on anode for 60 kW dissipation, approx.	18	gpm
Maximum outgoing water temperature	70	°C
Type of Cooling — ML-6697	Forced-air	
Air flow on anode for 35 kW dissipation	Pressure: 1700 cfm at 7.8" water*	
	Exhaust: 1970 cfm at 8.4" water*	
Maximum incoming air temperature	50	°C
Maximum Envelope Temperature	165	°C†
Net Weight, approximate		
ML-6696	17	lbs.
ML-6697	43	lbs.

*When used with ML-6697 air distributor F-17759.

†Auxiliary air flow of 50-100 cfm is required and should be distributed to maintain a uniform glass temperature, not greater than 165°C, around the circumference of the seals. At high frequencies or high ambient temperature, additional air flow may be required.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS
(Continuous Commercial Service)
VALUES APPLY TO BOTH TYPES UNLESS OTHERWISE SPECIFIED

Audio-Frequency Power Amplifier and Modulator Class B

Maximum Ratings, Absolute Values

D-C Plate Voltage	16000	volts
Max.-Signal D-C Plate Current*	11	amps
Max.-Signal Plate Input*		
ML-6696	120	kW
ML-6697	110	kW
Plate Dissipation		
ML-6696	60	kW
ML-6697	35	kW

Typical Operation (Values are for two tubes)

	ML-6696		
D-C Plate Voltage	10000	12000	volts
D-C Grid Voltage	−450	−600	volts
Peak A-F Grid-to-Grid Voltage	1750	2120	volts
Peak A-F Plate-to-Plate Voltage	16000	19200	volts
Zero Signal D-C Plate Current	3.0	2.0	amps
Max.-Signal D-C Plate Current	17.4	20.0	amps
Effective Load Resistance, Plate-to-Plate	1170	1230	ohms
Max.-Signal Driving Power, approx.	550	600	watts
Max.-Signal Power Output, approx.	110	152	kW

*Average over any audio-frequency cycle of sine-wave form.

Radio Frequency Power Amplifier Class B

Carrier conditions per tube for use with a maximum modulation factor of 1.0.

Maximum Ratings, Absolute Values

D-C Plate Voltage	16000	volts
D-C Plate Current	9	amps
Plate Input		
ML-6696	90	kW
ML-6697	55	kW
Plate Dissipation		
ML-6696	60	kW
ML-6697	35	kW

Typical Operation

	ML-6696		
D-C Plate Voltage	12000	12000	volts
D-C Grid Voltage	−550	−550	volts
Peak R-F Grid Voltage	510	640	volts
Peak R-F Plate Voltage	5300	5300	volts
D-C Plate Current	4.3	6.8	amps
D-C Grid Current	0	0	mA
R-F Load Resistance	780	500	ohms
Driving Power, approx.†	450	1500	watts
Power Output, approx.	18	28	kW

†At crest of audio-frequency cycle with modulation factor of 1.0.

Plate-Modulated R-F Power Amplifier Class C Telephony

Carrier conditions per tube for use with a maximum modulation factor of 1.0.

Maximum Ratings, Absolute Values

D-C Plate Voltage	10000	volts
D-C Grid Voltage	−3200	volts
D-C Plate Current	8.5	amps
D-C Grid Current	2.0	amps
Plate Input	81	kW
Plate Dissipation		
ML-6696	40	kW
ML-6697	23	kW

Typical Operation

D-C Plate Voltage	9500	volts
D-C Grid Voltage	−1600	volts
Peak R-F Grid Voltage	2300	volts
Peak R-F Plate Voltage	7800	volts
D-C Plate Current	8.4	amps
D-C Grid Current	0.90	amp
R-F Load Resistance	510	ohms
Driving Power, approx.	2.0	kW
Power Output, approx.	60	kW

R-F Power Amplifier and Oscillator Class C Telegraphy

Key-down conditions per tube without amplitude modulation‡

Maximum Ratings, Absolute Values

D-C Plate Voltage	16000	volts
D-C Grid Voltage	−3200	volts
D-C Plate Current	11	amps
D-C Grid Current	2.0	amps
Plate Input	120	kW
Plate Dissipation		
ML-6696	60	kW
ML-6697	35	kW

Typical Operation

D-C Plate Voltage	10000	15000	volts
D-C Grid Voltage	−1200	−1600	volts
Peak R-F Grid Voltage	1900	2120	volts
Peak R-F Plate Voltage	8000	12500	volts
D-C Plate Current	10.0	7.0	amps
D-C Grid Current	0.81	0.30	amp
R-F Load Resistance	440	970	ohms
Driving Power, approx.	1.5	0.60	kW
Power Output, approx.	72	80	kW

‡Modulation essentially negative may be used if the positive peak of the envelope does not exceed 115% of carrier conditions.

CHARACTERISTIC RANGE VALUES FOR EQUIPMENT DESIGN

Characteristics	Conditions		Minimum	Limits Bogey	Maximum	
Grid Voltage	e_b=1500 volts; i_b=48 amps	e_c:	—	—	1000	volts
Grid Current	e_b=1500 volts; i_b=48 amps	i_c:	—	—	15	amps
Plate Voltage	E_c=0 Vdc; I_b=3.0 Adc	E_b:	1.9	2.4	2.9	kVdc
Plate Voltage	E_c=−200 Vdc; I_b=3.0 Adc	E_b:	5.6	6.4	7.2	kVdc
Grid Voltage	E_b=15.0 kVdc; I_b=0.020 Adc	E_c:	−700	−820	−940	Vdc
Plate Power Output	E_b=15.0 kVdc; I_b=7.0 Adc; E_c=−1600 Vdc; I_c=0.30 Adc	P_o:	68	—	—	kW

MAXIMUM FREQUENCY RATINGS

Maximum ratings apply up to 30 MHz except as noted. The tube may be operated at higher frequencies provided the maximum values of plate voltage and power input are reduced according to the tabulation on the right. (Other maximum ratings are the same as shown above.) Special attention should be given to adequate ventilation of the bulb at the higher frequencies.

Frequency	30	50	70 MHz
Percent Maximum Rated Plate Voltage and Plate Input			
Class B	100	80	55
Class C	100	75	50

Introduction

These tubes, as all high-power vacuum tubes, require some aging when they are first used in any new equipment or new environment. As the system power level increases, particularly if attended by a decrease in impedance level, it becomes increasingly important to spend enough time to acclimate the tube to the desired conditions of operation. *There is no substitute for seasoning the tube in the actual equipment in which it is to operate.* Once the procedure has been followed, however, the tube generally will be available for substantially immediate operation, unless it has been idle for an extended period of time, say three months or more.

Aging Procedure

The aging schedule will vary with the particular operating and environmental conditions. A general procedure which will serve as a starting point is to operate the tube for approximately one-half hour at each of the following steps:

(a) filament voltage only;

(b) partial plate voltage, drive and load, up to about one-half normal;

(c) full plate voltage, drive and load.

The length of time necessary for break-in to insure reliable operation can vary widely. Only experience will tell whether the above procedure can be shortened, or whether steps (b) and (c) must be extended, perhaps by a factor of two or three. The major factors affecting break-in time are the *method of applying plate voltage,* the type of *protective circuitry* available to remove power in the event of a fault, and, for a spare tube, the length of time since it had been removed from normal operation.

Plate voltage is applied preferably by continuous or stepped control. Snap-on of full plate voltage with no load may develop excessive transients which cause breakdown in the tube or other circuit components. If the voltage must be snapped on at full value, at least some load should be placed on the power transformer to limit transients to 120 percent of the d-c voltage.

Tube Protection

Fault overloads, due to tube or circuit instabilities, may result in the following conditions:

(a) liberation of gas in the tube;

(b) gross damage to internal elements, e.g. melting of grid wires;

(c) external arcing over electrodes, with damage to seals and possible puncture of envelope insulator.

A tube which becomes gassy often can be cleaned up successfully by patient reaging. The other conditions listed above are usually catastrophic.

The criteria for tube protection are the total energy which may be imparted to the tube, and the peak voltage which may appear across the electrodes. The total energy available depends on the *power source impedance,* including effect of transmission lines, and the *energy stored* in the transformer and filter components; on the *series resistance* in the circuit; and on the *duration of the discharge* or fault condition.

Primary power characteristics often are not known by the equipment designer, and the major energy-storage components usually are fixed by circuit performance requirements. Tube protection, then, is reduced to limiting surges by the design of certain components, including in the circuit

at least some dissipative elements, i.e. resistance, and to sensing and removing any incipient surge as quickly as possible. The foregoing uncertainties make it difficult to specify the minimum requirements for sufficient tube protection under a given set of circumstances.

Protective Devices and Circuitry

Heretofore, it has been customary to equip plate and grid circuits with overload relays adjusted to open the circuit breakers within one-tenth of a second. In many applications, particularly where the impedance of the primary power source is low or where there is appreciable stored energy, the devices referred to above offer inadequate protection.

For high reliability and freedom from gassing and catastrophic failures, the use of an electronic shorting device or *"crowbar"* is recommended. In this case a thyratron, ignitron, or other suitable gaseous conduction device is connected to short the rectifier output to ground within 50 microseconds in the event of a fault condition. The electronic crowbar functions to divert the fault energy from the protected tube until the relay and circuit breakers act. Where multiple tubes are used with a common power supply, this type of crowbar is certainly necessary. This type of high-speed removal of fault energy has been extremely effective in reducing break-in time, and the lower the power supply impedance, the more impressive is the effect.

In some cases adequate protection can be obtained by using a vacuum switch, (a) connected as above, or (b) as a circuit breaker, replacing the usual slower acting types. These devices can divert, or remove, the fault energy in the order of one-half cycle. A vacuum-switch circuit breaker can, of course, be used to advantage in combination with the high-speed electronic shorting device. *The latter arrangement probably gives the best over-all protection to the tube and other circuit components.*
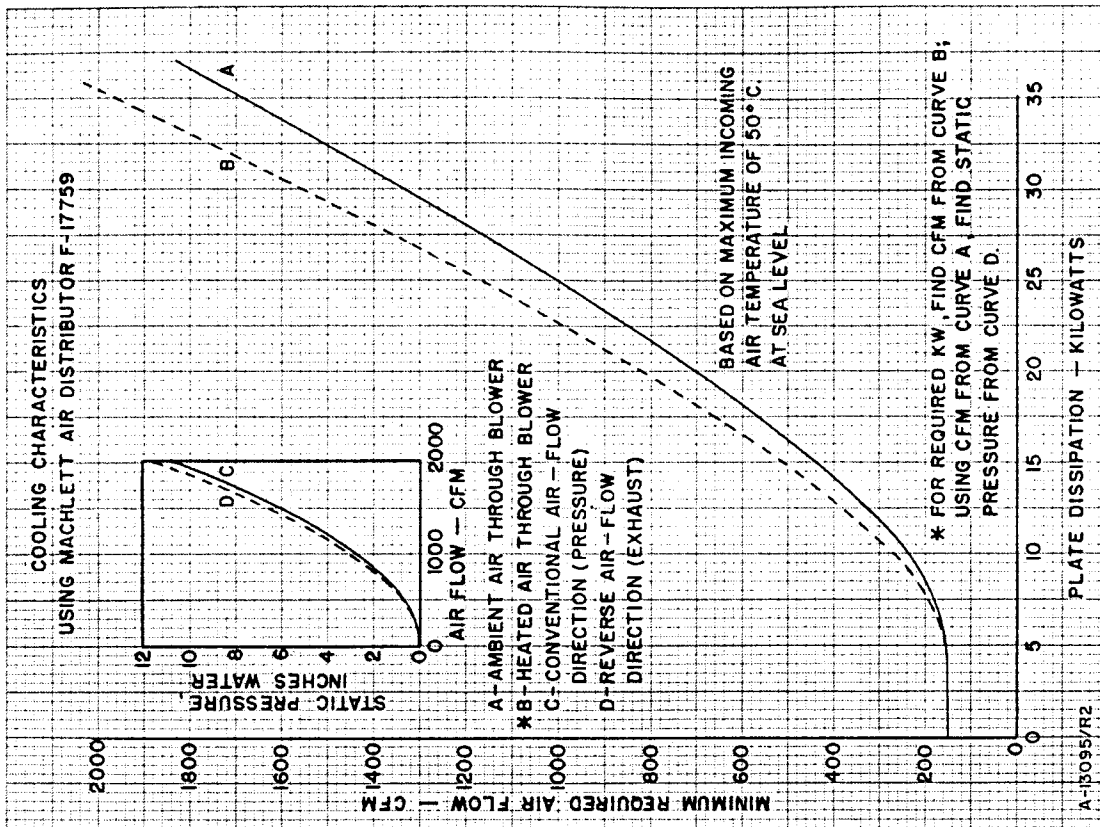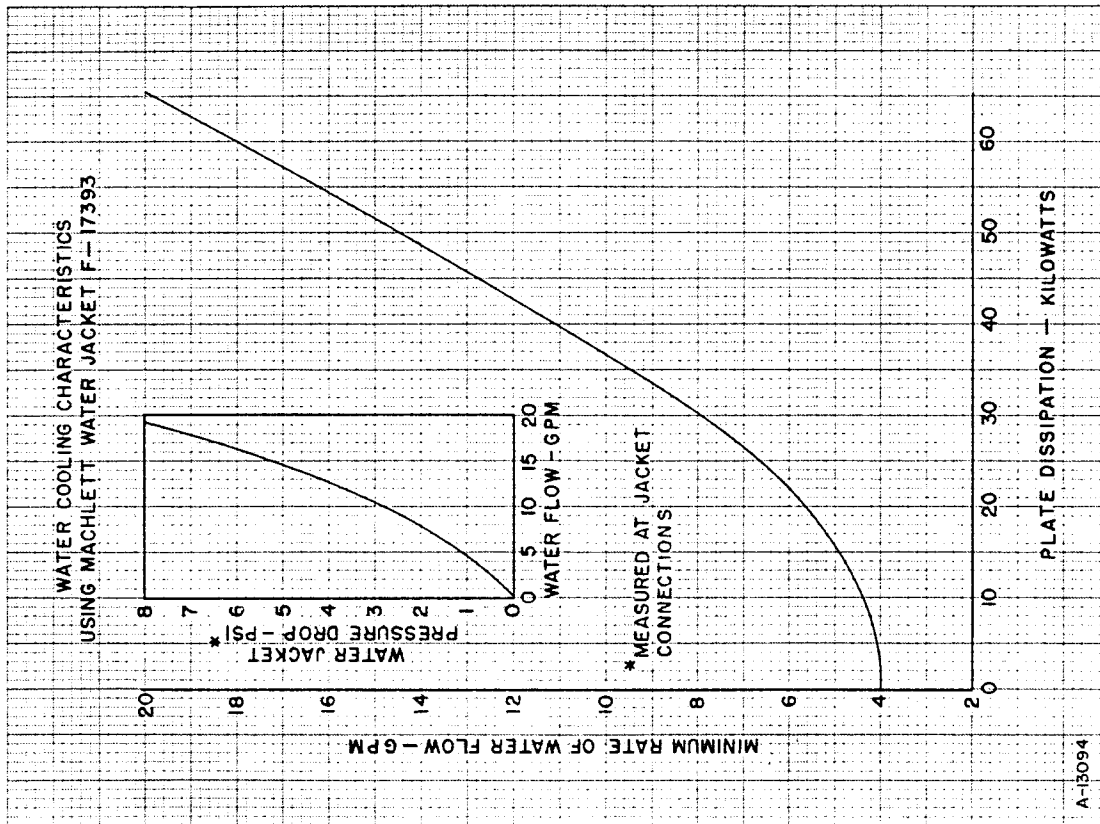
In addition, some *series resistance* should be used in the output of the power supply to limit the surge current from the transformer. Preferably, resistors may be placed in series with each rectifier lead to provide equal protection with substantially less power dissipated during normal operation. The amount of resistance will vary with circuit conditions and the speed of the protective circuitry, but the following values can be given as a guide:
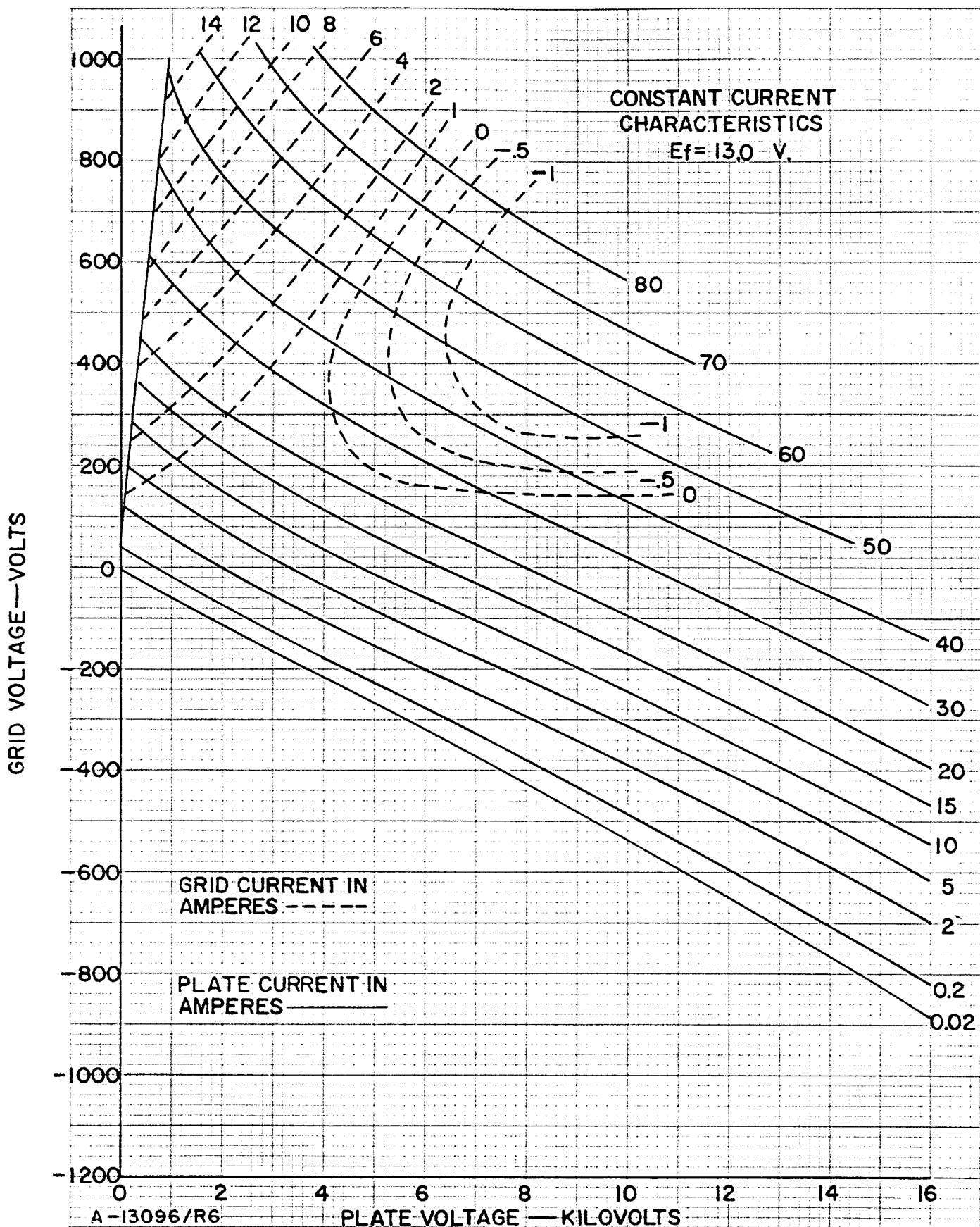
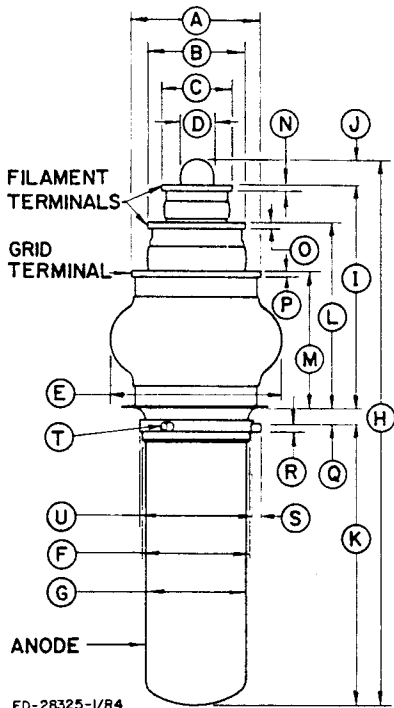| Maximum Power Output of Rectifier	120	250	500	1000	kW
Series Resistor	10	20	35	50	Ohms

The voltage ratings of these tubes are established so that normal operation will not cause arcs to develop across the tube envelope. Any external arcing, therefore, is an indication that the rated voltages have been exceeded. To lessen the chance of permanently damaging the tube, it is helpful to attach suitable *sphere gaps,* or rings, to the electrode terminals. If the sphere gaps are properly installed, the most probable breakdown path is between the gaps rather than over the tube envelope. The gap separation must be carefully adjusted for each application. The spacing from the tube envelope to the gaps or rings, in general, should be equal to or greater than the gap separation.

Maintenance

The anode cooling fins of the ML-6697 must be kept free from films of foreign materials, which will impair heat flow. To keep fins clean, it is suggested that ultrasonic cleaning or wire-brushing of the anode cooling surfaces be performed on a routine maintenance basis.

COOLING CHARACTERISTICS

USING MACHLETT AIR DISTRIBUTOR F-17759

AIR FLOW — CFM

STATIC PRESSURE, INCHES WATER

A—AMBIENT AIR THROUGH BLOWER
*B—HEATED AIR THROUGH BLOWER
C—CONVENTIONAL AIR—FLOW DIRECTION (PRESSURE)
D—REVERSE AIR—FLOW DIRECTION (EXHAUST)

BASED ON MAXIMUM INCOMING AIR TEMPERATURE OF 50°C. AT SEA LEVEL.

* FOR REQUIRED KW, FIND CFM FROM CURVE B; USING CFM FROM CURVE A, FIND STATIC PRESSURE FROM CURVE D.

PLATE DISSIPATION — KILOWATTS

MINIMUM REQUIRED AIR FLOW — CFM

A-13095/R2

COOLING CHARACTERISTICS — ML-6697

WATER COOLING CHARACTERISTICS
USING MACHLETT WATER JACKET F—17393

WATER FLOW—GPM

WATER JACKET PRESSURE DROP—PSI*

*MEASURED AT JACKET CONNECTIONS

PLATE DISSIPATION — KILOWATTS

MINIMUM RATE OF WATER FLOW—GPM

A-13094

COOLING CHARACTERISTICS — ML-6696

CONSTANT CURRENT
CHARACTERISTICS
Ef= 13.0 V.

GRID VOLTAGE—VOLTS

GRID CURRENT IN
AMPERES – – – –

PLATE CURRENT IN
AMPERES

A –13096/R6   PLATE VOLTAGE — KILOVOLTS

FILAMENT
TERMINALS

GRID
TERMINAL

ANODE

ED-28325-1/R4

ML-6696

DIMENSIONS FOR OUTLINE OF ML-6696

Ref.	Inches			Notes
	Minimum	Nominal	Maximum	
A	4.619	4.650	4.681	
B	3.469	3.500	3.531	
C	2.469	2.500	2.531	
D	—	1.12	1.19	
E	—	5.94	6.13	
F	3.990	3.995	4.000	
G	3.485	3.500	3.515	
H	—	19.16	19.38	
I	7.75	7.88	8.00	
J	—	.94	1.00	
K	9.75	9.87	10.00	
L	6.50	6.62	6.75	
M	4.81	4.88	4.94	
N	.12	.18	—	
O	.12	.18	—	
P	.12	.18	—	
Q	.40	.44	.47	
R	.300	.310	.320	1
S	.28	.31	.35	1
T	—	120°	—	1
U	4.00	4.03	4.06	

NOTES:
1. Three bayonet pins for water jacket connection, diameter (R), length (S), nominally (T) degrees apart.

FILAMENT
TERMINALS

GRID
TERMINAL

ANODE
AIR
COOLER

ED-28310-1/R6
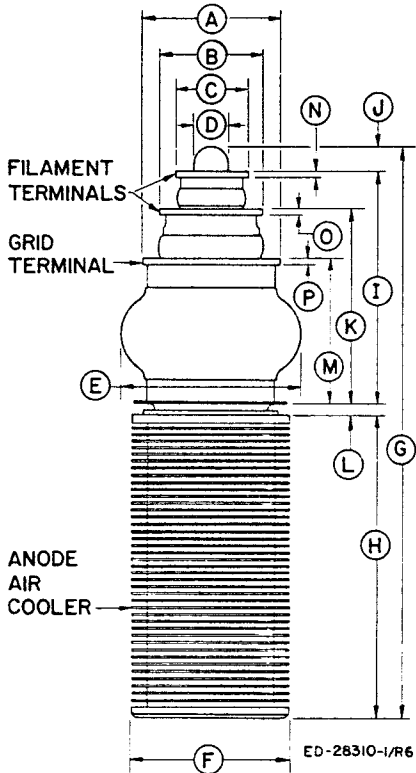
ML-6697

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	Minimum	Nominal	Maximum	
A	4.619	4.650	4.681	
B	3.469	3.500	3.531	
C	2.469	2.500	2.531	
D	—	1.12	1.19	
E	—	5.94	6.13	
F	5.219	5.250	5.281	
G	—	19.36	19.88	
H	10.00	10.12	10.25	
I	7.75	7.88	8.00	
J	—	.94	1.00	
K	6.50	6.62	6.75	
L	.31	.45	—	
M	4.81	4.88	4.94	
N	.12	.18	—	
O	.12	.18	—	
P	.12	.18	—	