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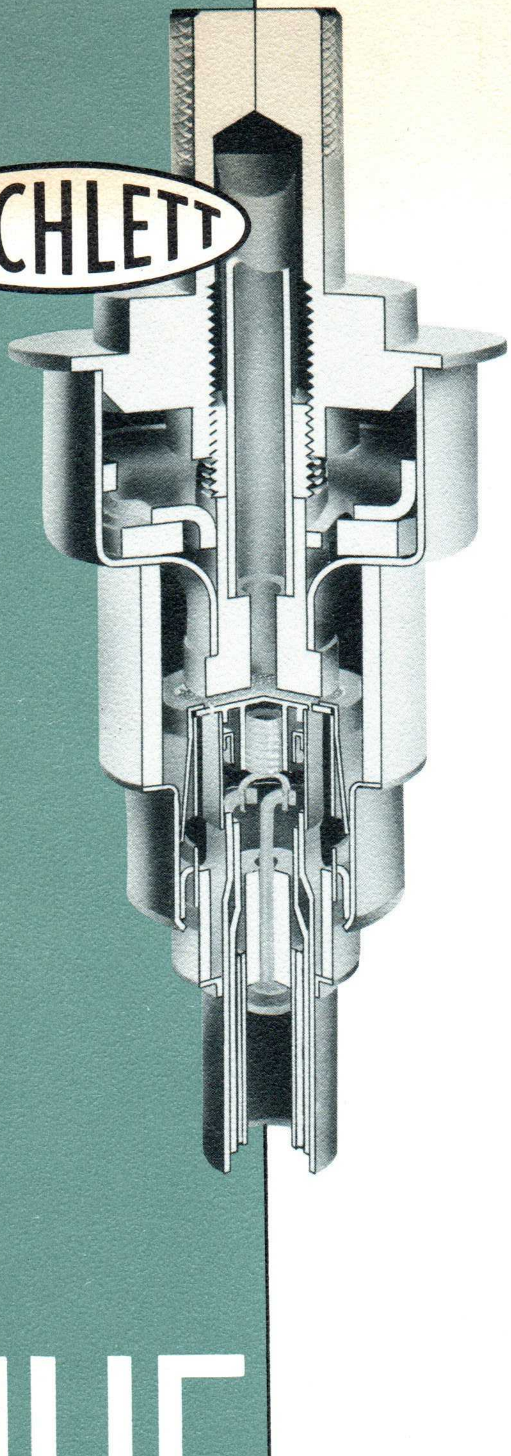

UHF PLANAR TRIODES

2ND ED.

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Design Considerations in UHF Planar Transmitting Triodes

by

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Design Considerations

This paper discusses the essential design considerations of UHF triodes and shows how the particular choice of the physical dimensions of electrode area, interelectrode spacings, grid wire diameter and pitch affect the operation of the tube under Class B and C conditions. In particular, the study will be centered on planar electrode structures, but most of what is said applies equally well to cylindrical electrode structures.

The three electrical parameters of interest to the circuit engineer which are of prime importance in designing a tube are (1) maximum frequency (2) power output (3) minimum d.c. plate voltage. In order to have an example in mind, the 2C39A tube will be analyzed. Here the requirements are (1) 600 mc/sec (2) 20 watts (3) 400 volts. The figure of 600 mc/sec has been chosen as the maximum frequency below which transit time effects are negligible. The tube works well at 2500 mc/sec where the transit time is nearly 2π radians. Under such an extreme of frequency the electronic efficiency is 50% of the low frequency value and increased circuit losses reduce the overall efficiency to 15 or 20%. This tube is also designed to work as high as 1000 plate volts, permitting higher power output at all frequencies than obtainable at the lower plate voltage figure.

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Cathode

The next step is to see how the three requirements for the equipment designer above are interpreted in tube design. The first consideration is cathode area. From the required output power and plate voltage, the tube designer needs an overall estimate of plate efficiency which in turn gives the required average plate current. The average grid current must also be known; it depends on a variety of factors which will be discussed later. For the present we shall assume that the average grid current will be 1/3 of the average plate current. The cathode current is, of course, the sum of grid and plate current. For the present an overall circuit plus tube plate efficiency of 50% will also be assumed. These requirements all add up to the fact that the cathode shall furnish an average d.c. current of 133 ma. Assuming a ratio of 4 for the peak to average cathode current, the instantaneous peak cathode current becomes about 530 ma. The ratio of 4 is based on a plate current angle of flow of about 140°:

$$
\begin{aligned}
E_p I_p &= P_o/n \\
n &= 50\% \\
E_p &= 400 \text{ volts} \\
P_o &= 20 \text{ watts} \\
I_p &= 100 \text{ ma} \\
I_k &= {}^{4/3}\, I_p = 133 \text{ ma} \\
i_k &= {}^{4}\, I_k = 532 \text{ ma},
\end{aligned} \qquad (1)
$$

where
E_p = d.c. plate voltage
I_p = d.c. ave. plate current
n = efficiency
P_o = power output
I_k = d.c. ave. cathode current
i_k = peak r.f. cathode current

The next question is what cathode area is required to give approximately 133 ma average current and 530 ma peak current? At this point the question of desired life must be raised; i.e. for uhf operation the electrode area should be as small as possible, but for good cathode life this area should be large. Consider for example a 6SN7 receiving tube; I_k ave = 10 ma per side and the cathode area is about .7 cm^2, or the average cathode current density is 15 ma/cm^2. With suitable choice of tube materials, such a tube can be made to run 30,000 hours. Obviously a cathode area of 9 cm^2 for 20 watts output power is incompatible with uhf design. In the 2C39A an area of 0.5 cm^2 was chosen, i.e., the cathode is to run with an average current density of 265 ma/cm^2 or nearly 18 times the current density of a 6SN7. The peak cathode current, j, is 1.06 Amps/cm^2. In spite of this large difference in cathode current density, 2C39A cathodes have given lives of 10,000 hours or greater under favorable conditions, i.e. regulated filament voltage, good cooling, etc.; i.e. conditions easy to achieve in ground based equipment.

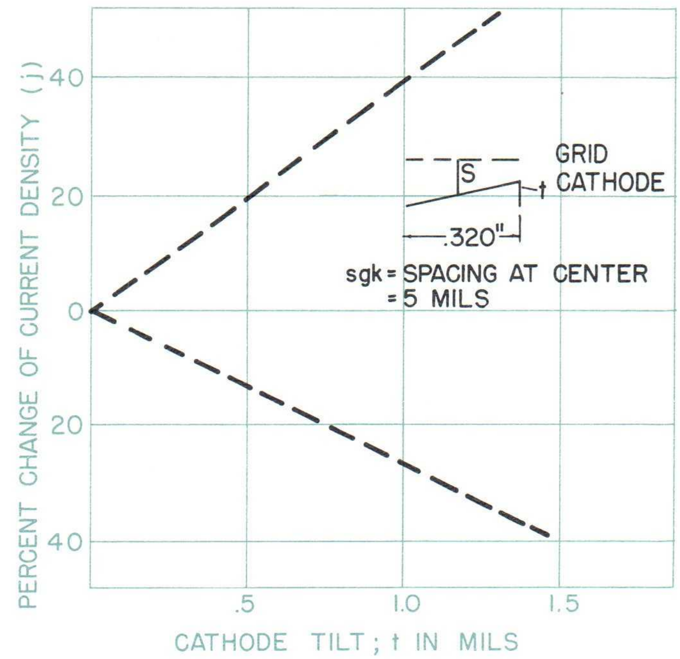

Figure 1 — Relation between plate current, transconductance and interelectrode spacings of 2C39A.

Grid

Having arrived at a figure of 0.5 cm^2 for cathode area, the next question is what should be the grid-cathode spacing? This is easily determined by transit time considerations and cathode current density.

The transit time T is given by:

$$T = K\left(\frac{d}{j}\right)^{1/3} \qquad (2)$$

where K = function of frequency
d = grid cathode spacing
j = peak cathode current density

If T is to be less than 0.3 radian at 600 mc., then d cannot be greater than .005 in. or 1/8 of a mm. For a complete analysis of transit time effects see reference 1.

Having determined the maximum grid-cathode spacing, the next question to be decided is the grid wire diameter and pitch. The pitch is readily determined by the requirement of a uniform field at the cathode, i.e. the spacing between grid wires[2] cannot be much greater than the grid-cathode spacing if the grid is to control the emission from all the cathode. The grid pitch becomes .006 in., i.e. about 1.2 times the grid-cathode spacing. Since the larger the diameter of the grid wire the greater the current intercepted by the grid, this wire should be as small as possible. Determination of the wire diameter depends upon the mechanical and thermal properties of suitable grid wires. Unless the grid is thermally stable the grid plate capacitance under load will vary when the grid bows, thereby detuning the output circuit. For this reason the wire diameter is chosen such that the "screening fraction" i.e. the geometrical shadow area of the grid is about 30%. This gives a wire diameter of .0018 in. Reducing this wire size gives reduced drive power at the expense of frequency stability.

In actual practice a parallel wire grid under Class C conditions is very unsatisfactory. The longest wires for a cathode of 0.5 cm^2 are nearly 1 cm in length. Invariably one or more wires will bow and short to the cathode. This may happen only during improper tuning or other abuse, but nevertheless the tube's usefulness is destroyed. The best solution is to use a mesh grid. By using smaller wires, .0012 in. diameter, at a pitch of .0072 in. both ways, the thermal stability of the grid is vastly improved and the screening fraction is unchanged.

The final dimension to be established is the grid-plate spacing. The factors to be considered here are (1) grid-plate capacitance vs. cavity foreshortening and circuit Q (2) maximum voltage (3) μ of the tube. If a spacing of .0025 in. is taken and the tube is to be run at a maximum d.c. plate voltage of 1000 volts, the peak gradient between plate and grid will be of the order of 100,000 volts/in. The active output capacitance will be 1 $\mu\mu$f and the μ will be 100. Halving this spacing will double the voltage gradient and the capacitance and will halve the μ. Doubling this spacing will halve the voltage gradient and the capacitance and double the μ. It will also increase the grid-anode transit time at the higher frequencies. The ideal choice would depend on the particular application. In the 2C39A

[1]Wang, C., "Large-Signal High-Freqency Electronics of Thermionic Vacuum Tubes," Proc. IRE pgs. 200-214, April 1941.

[2]Bennett, W. R., and Peterson, L. C., "The Electrostatic Field in Vacuum Tubes," Bell Sys. Tech. Journal, pgs. 304-314, April 1949.

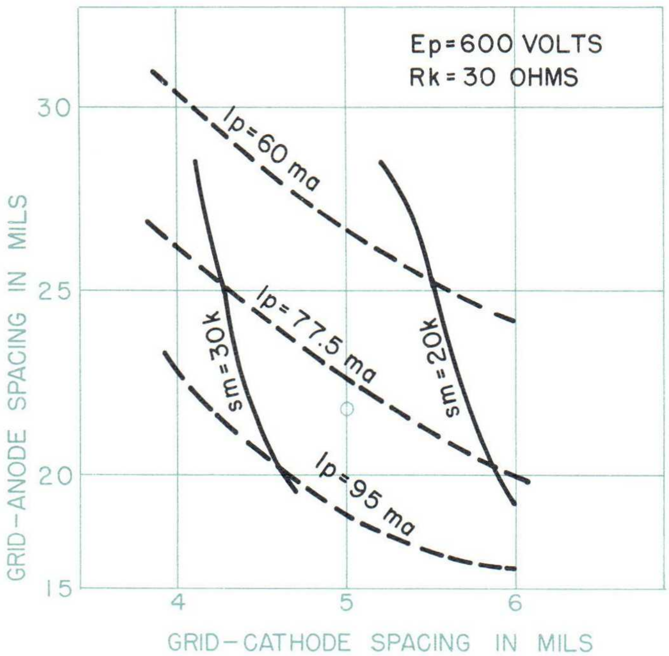

Figure 2 — Effect of variations in grid-cathode spacings on cathode current density.

for general use the spacing of 0.0225 in. was adopted.

To review the design, a tube was to be made with zero transit time at 600 mc, but usable to 2500 mc; it was to operate efficiently with a plate voltage as low as 400 V with a power output of 20 watts; it was to operate with plate voltages as high as 1000 volts. First, a cathode area of 0.5 cm^2 was selected based on a cathode average current density of 260 ma/cm^2. The grid cathode spacing should be less than .005 in. based on low transit angle at 600 mc. A mesh grid was used whose pitch was .0072 in. each way, and the grid wire diameter selected on the necessary mechanical and thermal stability became .0012 in. The grid-plate spacing was selected as 0.0225 in. as a compromise between output capacitance, voltage gradient, μ and grid-plate transit angle.

Planar Triode – Circuit Operation vs. Mechanical Tolerances

Having arrived at a tube design, the second part of this paper is concerned with the operation of this tube in circuits. Of course if all tubes made were exactly alike in every detail, they would all work exactly alike in circuit applications. The effects of tolerances on mechanical dimensions give rise to variations in static data as well as in operating circuits. Figure 2 shows the effects of variations in grid-cathode and grid-anode spacings on the measured plate current and transconductance under MIL specifications; i.e. $E_p = 600$ volts, $R_k = 30$ ohms. Figure 2 gives lines of constant static plate current for the minimum and maximum values of the MIL specification. Also shown are minimum and maximum values of transconductance. The center circle O shows the design center of the cold grid-cathode and grid-anode spacings of 5 and 22.5 mils respectively. This mechanical spacing bogey centers on the figure for MIL average plate current and transconductance. The latter is not quite geometrically centered on the diagram since s_m varies with static plate current. From Figure 2 it is apparent that the assembly tolerances on grid-anode spacing are not critical. The grid-cathode spacing of 5 mils $\pm$ ½ mil is difficult to hold unless elaborate mounting means is provided. Furthermore, this spacing depends on cathode temperature. Another variable item not considered in Figure 2 is the bulk resistance of the cathode coating. This resistance is an unbypassed cathode resistance of a few ohms which will shift the static plate current from 5 to 15 ma lower than shown, depending on the degree of activity of the individual cathode.

In addition to plate current and s_m, the interelectrode

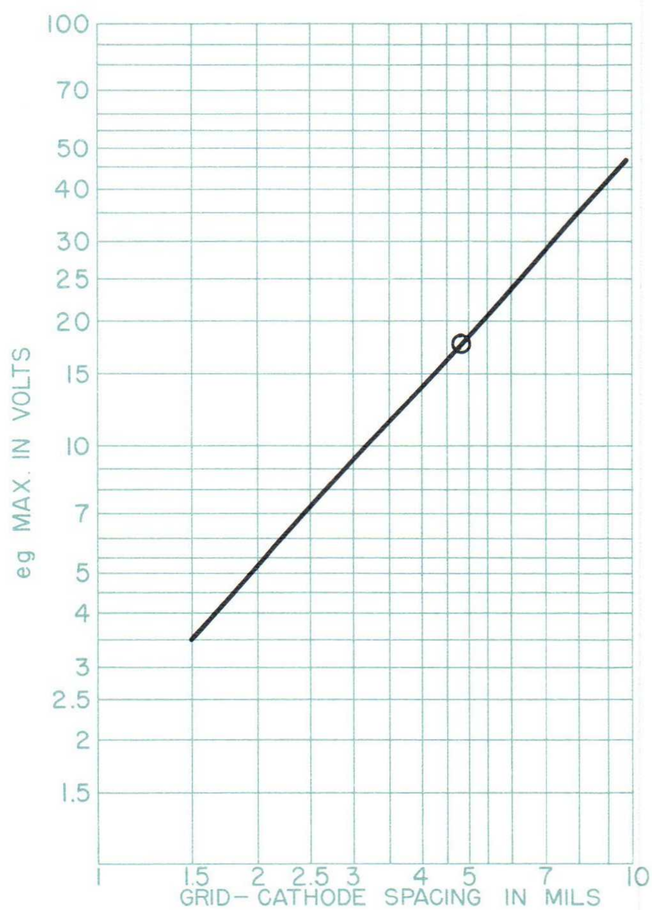

Figure 3 — Instantaneous maximum grid voltage required for a cathode current density of 1.06 amps/cm² for various grid cathode spacings of 2C39A.

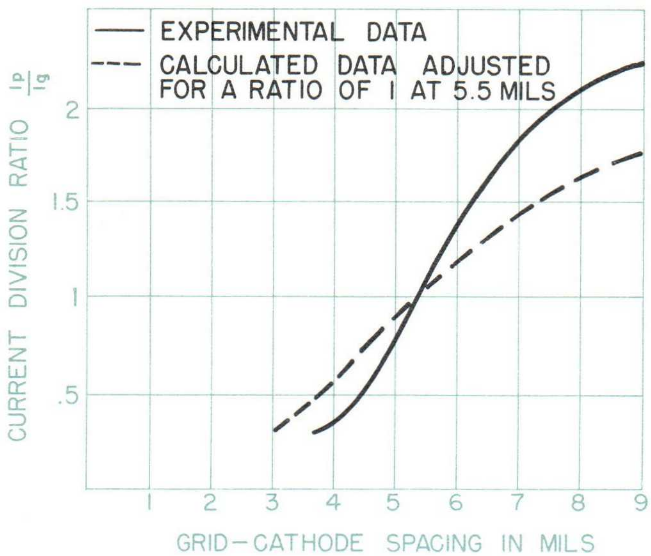

Figure 4 — Ratio of peak plate current to peak cathode current at fixed peak grid voltage as a function of grid-cathode spacing.

spacings determine the interelectrode capacitances. It is possible to maintain the desired tube spacings and vary capacitances slightly by changing electrode area or the form of the envelope insulation separating the electrodes.

Other tolerance effects are the parallelism of the electrodes, principally the grid and cathode surfaces. The ratio of the cathode diameter to the grid-cathode spacing is 70 to 1. The effect on cathode current density vs. tilt is shown in Figure 1. If the cathode tilt amounts to 1 mil, the current density is 40% high on the close side and 33% low on the far side. Besides resulting in excessive cathode current density on the closer part of the cathode, this situation also gives rise to poorer current division between plate and grid.

Having discussed the effects of mechanical tolerances on negative grid static plate current and transconductance, the next problem is to see what happens in the region of positive grid drive. The first problem is to find the peak driving voltage required to deliver the peak cathode current of 1.06 Amps/cm². It will be remembered that this is the cathode current density required for 20 watts output with $E_p = 400$ volts. In Class C operation the plate voltage is always at its minimum value when peak current is passed through the tube. Since the 2C39A has a μ of 100, the peak cathode current is determined largely by the peak grid voltage. (See Reference 3.) This simplifies the usual triode equation to:

$$j_k = \frac{i_k}{A} = \frac{2.34 \times 10^{-6} e_g^{3/2}}{S_{gk}^2} \qquad (3)$$

where

j_k = peak cathode current density = 1.06A/cm²
i_k = peak cathode current
A = cathode area = 0.5 cm²
e_g = peak positive grid voltage
S_{gk} = grid-cathode spacing

Figure 3 shows how e_g varies with grid-cathode spacing. A circle is placed at the spacing design centers and it is seen that a value of e_g of 18 volts is required. On our tolerance limits of $\pm\frac{1}{2}$ mil, e_g varies from 16 to 20 volts.

Now the peak grid and plate currents are required in order to obtain the driving power, efficiency, etc. An approximate formula for calculating the ratio of the peak grid current, i_g, to the peak cathode current, i_k, has been recently given by Pohl and Rogers[4]:

$$\frac{i_g}{i_k} = \frac{d}{p}\left(\frac{S_{ga} + S_{gk}}{S_{gk}}\right)^{2/3}\left(\frac{e_g}{e_p}\right)^{1/2} \qquad (4)$$

i_g = peak grid current
i_k = peak cathode current
d = grid wire diameter
p = grid wire spacing
S_{ga} = grid-anode spacing
S_{gk} = grid-cathode spacing
e_g = peak positive grid swing
e_p = minimum peak plate swing

Using the values for d, p, S_{ga}, S_{gk} given in the first part of this paper gives:

$$\frac{i_g}{i_k} = 0.93\left(\frac{e_g}{e_p}\right)^{1/2}$$

From this equation it is obvious that e_p must be large compared to e_g. In fact, for i_g to be as low as 50% of i_k, e_p must be at least 3.5 times e_g. Let us assume e_p to be 100 volts, then

	$i_g = .42\ i_k$
but	$i_k = 530$ ma
therefore	$i_g = 220$ ma
and	$i_p = i_k - i_g = 310$ ma

A calculation of Class C Grounded Grid Operation from published data for these conditions, i.e.

e_g = 17.5 volts
e_p = 100 volts
i_p = 310 ma
i_g = 220 ma

gives the following results:

Grid Bias	—14	volts
Plate Current Angle of Flow	140°	
Average Plate Current	72	ma
Average Grid Current	46	ma
Power Output	21	watts
Plate Power Input	29	watts
Apparent Efficiency	72.5	%
Driving Power	3.3	watts
Power Gain	6.3	
Load Resistance	2600	ohms
Grid Dissipation	0.67	watts

These figures do not include circuit losses, hence the

[3] Spangenberg, K. R., "Vacuum Tubes" 1948, pgs. 183-186.

[4] (a) Pohl, W. J., and Rogers. D. C., "U.H.F. Triodes" Wireless Engineer pgs. 47-52, Feb. 1955.
(b) Spangenberg, K. R., "Vacuum Tubes" 1948, pgs. 224-230.

actual power output will be 10% or so less than shown. The drive power will also be greater.

It is obvious from this calculation, however, that in close-spaced triodes the minimum plate voltage must be several times the peak grid voltage, otherwise, the grid will steal a large part of the cathode current. This restriction on the plate voltage swing limits the maximum efficiency obtainable, and shows that for best efficiency a higher plate voltage is desirable.

Looking at the problem of the plate current to grid current ratio from the viewpoint of grid-cathode spacing variations gives the results shown in Figure 4. Here calculated data are compared with experimental data. These data are taken with $e_g = 8.5$ volts and $e_p = 50$ volts. The calculated curve has been adjusted to agree with the experimental data at a current ratio of 1 and a grid-cathode spacing of 5.5 mils.

Due to space charge effects, initial electron velocities and the difficulties of measuring the precise spacing, it is not surprising that the approximate Pohl and Rogers equation does not give precise quantitative data. However, it is obvious that the general form of the current division curve is predicted. The steepness of the curve shows that large variations in grid intercepted currents occur within the normal variations to be expected in grid-cathode spacings. In fact, the closer-spaced tubes have the poorer current division ratio! This fact explains why power output does not correlate with the negative grid transconductance test with zero grid current.

Fortunately, the picture is not as black as it first appears. The required positive grid drive decreases as the grid-cathode spacing decreases, hence it is not necessary to drive the grid as hard in a close-spaced tube.

From equation 3 it is seen that

$$e_g^{1/2} = \text{const. } S_{gk}^{2/3}$$

for fixed peak cathode current. Putting this information in equation (4) gives:

$$\frac{i_g}{i_k} = \frac{d}{p}\left(\frac{S_{ga} + S_{gk}}{S_{gk}}\right)^{2/3} \frac{\text{const. } S_{gk}^{2/3}}{e_p^{1/2}}$$

$$\frac{i_g}{i_k} \propto \left(\frac{S_{ga} + S_{gk}}{ep^{1/2}}\right)^{2/3} \qquad (5)$$

With S_{ga} fixed, closer-spaced tubes, when driven to the optimum e_g, actually give slightly better reduction in grid current. The numerator of the second member of equation (5) will decrease only a small amount with S_{gk} as S_{gk} is small compared to S_{ga}.

If a close-spaced tube is overdriven the power output will increase slightly due to the power fed through from the driving stage. Nevertheless, the positive grid voltage and current peaks flatten off due to the large grid current causing an i Z drop in the driver source impedance. Since the grid drive voltage is limited by this current saturation effect, the plate current wave also squares off, producing little net change in the fundamental plate current. This squaring off of the plate current pulse also introduces strong harmonics in the plate circuit if the impedance at these harmonic frequencies is appreciable.

A simple way to solve the grid current problem would be to halve the grid wire diameter. Unfortunately, this is not practical due to problems of grid stability and overheating. A mesh grid as described above has a little better current division ratio than a parallel wire grid of the same screening fraction and will show 10 to 20% higher output with constant driving power at high average grid currents, i.e., when the tube is pushed well into the region of diminishing returns. Under conditions of higher plate voltages, more power output and increased efficiency is achieved, i.e., it is not necessary to overdrive the grid.

Another inherent problem which comes up with low power uhf transmitting tubes is the problem of impedance levels. From the above calculation for 20 watts output at 400 volts plate voltage, it is seen that the load impedance the tube must see to operate properly is 2600 ohms. At higher plate voltages this impedance is greater. Since in most applications the power output is piped out at 50 ohms, there must be a 52 to 1 impedance step down ratio from the tube electrodes to the load. This step down ratio is achieved by setting up standing waves in the cavity. The loaded circuit Q must be large enough to provide this impedance multiplication. For this reason the unloaded cavity Q must be large for good circuit efficiency, since the circuit efficiency is given by

$$n = \frac{Q_u - Q_L}{Q_u}$$

No paper would be complete without a brief discussion on the oxide cathode. Although considerable improvements in available emission, stability and life of this type of cathode have been achieved over the past ten years, the physics and chemistry of this type of cathode[5,6] are far from understood. Initial emission varies somewhat from tube to tube and all tubes show emission deterioration on life. The greater the emission requirement the earlier in life deterioration will appear. For example, a 6SN7 tube may show no apparent deterioration for 20,000 hours, only because of the very modest emission requirements. A periodic peak emission test would show a gradual deterioration. The effects of variability in emission of new cathodes masks initial critical tests for current division ratio, power output, etc. Cathode life can be altered considerably by variations in the base nickel, oxide coating, parts cleaning and pumping methods. This work must be evaluated by operational life tests, and consequently progress is slow. High initial activity and long life appear to be somewhat incompatible.

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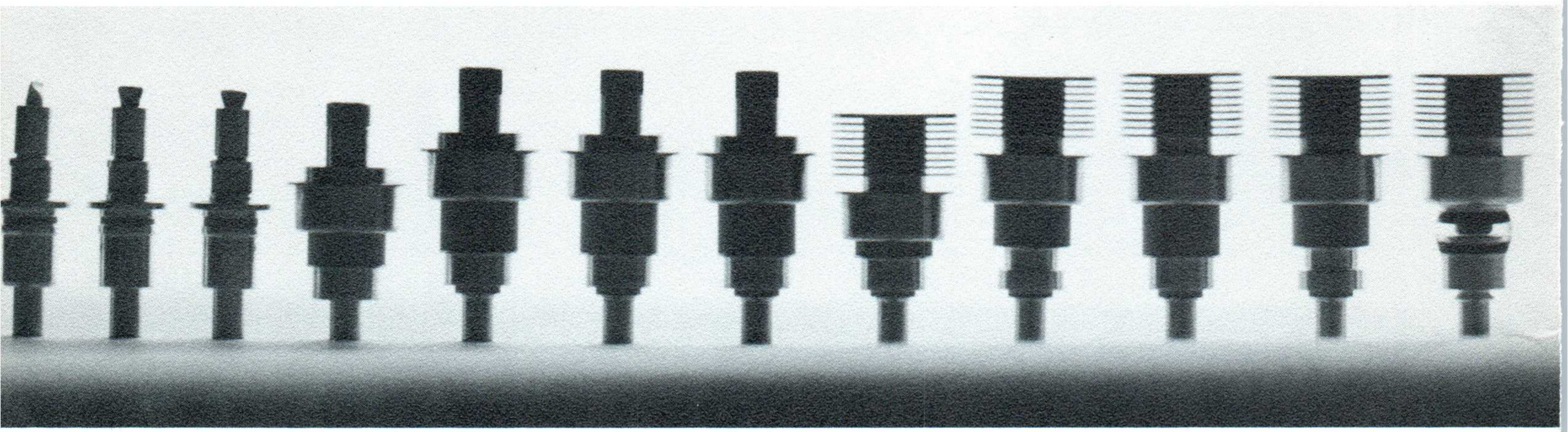
[5]Rittner, E. S., "A Theoretical Study of the Chemistry of the Oxide Cathode" Philips Res. Rev. pgs. 184-238, June 1953.

[6]Nergaard, L. S., "Studies of the Oxide Cathode" R.C.A. Review. Dec. 1952.

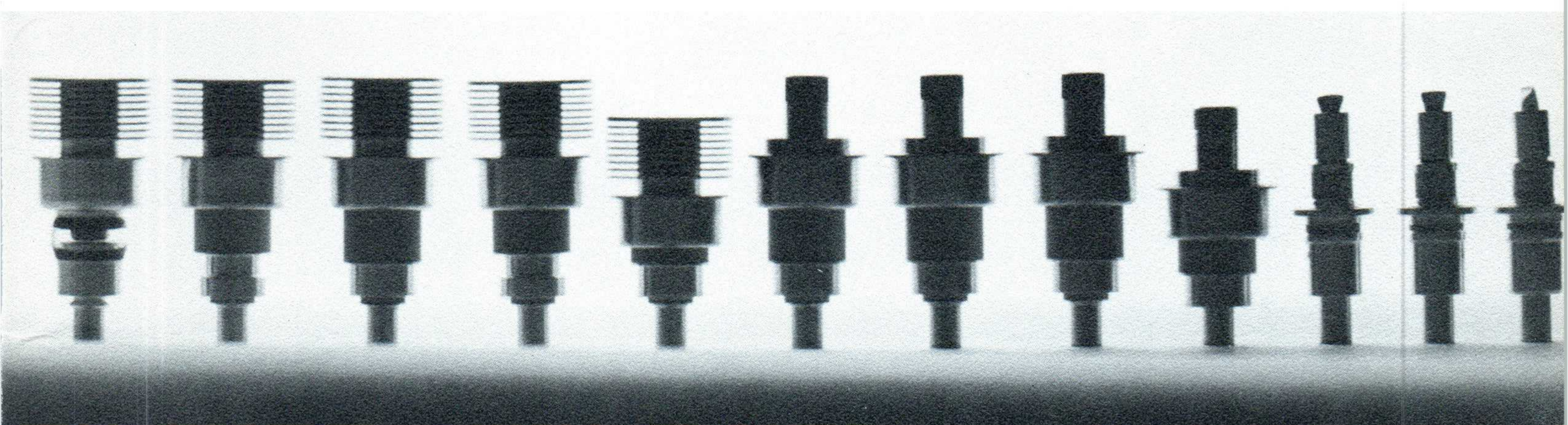
Frequency Stable Anode Design



Abstract

With the space age progressing rapidly, new circuit aspects enter into the picture and older ones are suddenly more important. Frequency stability is one of the latter. The intermittent operation of equipments in space probes requires that all transmitters operate stably and reliably after a short heater warm-up time. No additional stabilization time is permitted. A telemetering transmitter is cited as an example. One built with conventional tubes of the type 3CX100A5/7289 showed a drift of 12 Mc and more from the time the high voltage was applied until stable operation and full power output were reached. The time necessary for stabilization varied from 15 to 30 minutes. Tubes with cylindrical electrode structures would show similar results. The frequency shift could only be overcome by constant tuning. The new anode design to be discussed here has almost entirely reduced the frequency drift phenomenon caused by the tube. Using a new tube type having a frequency stable anode, the drift was reduced to a few tens of kilocycles and stable operation was reached in a matter of seconds. Furthermore, it was found that a variation in plate power input of ±25% did not affect frequency stability.

For



Planar UHF Tubes

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Introduction

Planar and cylindrical triodes and tetrodes have been and are being used in the power range of a few watts to 100 watts and more both in the VHF and UHF bands. In their present form both tube types show a change in grid-anode capacitance with a change in anode temperature. The change in grid-anode capacitance is evidenced by a variation in resonance frequency in the various circuits. As long as the tube is operating continuously and the anode dissipation remains constant, the usual tube is satisfactory. However as soon as the equipment must be used intermittently or if the duty of a particular pulsed circuit is drastically changed the conventional tubes are no longer acceptable. So far it has been attempted to design around these deficiencies, and as long as the equipment can be constantly tuned it is still usable. However for equipments designed for space application, frequency stable operating circuits become a factor of prime importance and new ways and means have been sought to overcome this shortcoming.

In the following we discuss the basic cylindrical and planar tube structures and the parameters which influence the change in grid-anode capacitance with a change in anode temperature.

Cylindrical Electrode Structure

In Figure 1, one of the two possible basic tube structures is shown. Using the equation for the capacitance of two concentric cylinders and forming the proportion $\triangle Cga/Cga$ we obtain

$$\frac{\triangle Cga}{Cga} = - \frac{\log_{10} e}{\log_{10}\left(\frac{r_1}{r_2}\right)} \left(\frac{\triangle r_1}{r_2}\right) \qquad (1)$$

The ratio $\triangle r_1/r_1 = \alpha \triangle T$

where α = linear thermal expansion coefficient of the anode

$\triangle T$ = change in anode temperature °C.

Substituting this in (1) we receive the final equation representing the grid-anode capacitance change with a change in anode temperature.

$$\frac{\triangle Cga}{Cga} = - \frac{0.43}{\log_{10}\left(\frac{r_1}{r_2}\right)} (\alpha \triangle T) \qquad (2)$$

Figure 2 shows the second basic cylindrical tube structure. In this case there is besides a decrease in capacitance, due to the anode radial expression as shown in equation (2), also an increase in the grid-anode capacitance due to an increase in the anode length l. The latter effect is expressed by

$$\frac{\triangle C}{C} = \frac{\triangle l}{l} = \alpha \triangle T \qquad (3)$$

Combining equation (2) and (3) we obtain the total change in grid-anode capacitance for a cylindrical tube structure as shown in Figure 2.

$$\frac{\triangle Cga}{Cga} = \left(1 - \frac{0.43}{\log_{10}\left(\frac{r_1}{r_2}\right)}\right) \alpha \triangle T \qquad (4)$$

Equation (4) shows that unless the ratio r_1/r_2 is fairly large the predominant effect is due to the radial expression of the anode. It furthermore shows that an electron tube having a cylindrical structure can be made with a constant grid-anode capacitance as the anode temperature varies only if the ratio of the plate cylinder i.d. to the grid cylinder o.d. is e or 2.718. This solution, however, is unsatisfactory since it would require an excessive grid-anode spacing to achieve this ratio. In UHF tubes the spacing is governed by space charge and transit time requirements which are in direct opposition to the above. Of course one could provide an auxiliary capacitor, which would offset the decrease in grid-anode capacitance. But any such solutions would deteriorate UHF tube design by adding additional passive capacitance between grid and anode.

A typical pencil tube incorporating the cylindrical tube structure, a nickel-iron anode and a 0.24 cm diameter cathode with a 0.2 cm^2 emitting area showed an increase of approximately 4 Mc at a center frequency of 2000 Mc with a change in anode temperature of 100° C. This value would increase about three times if the anode is made of copper. For tubes having a larger cathode diameter the detuning is worse. The r_1 and r_2 for this typical tube is 0.114 cm and 0.086

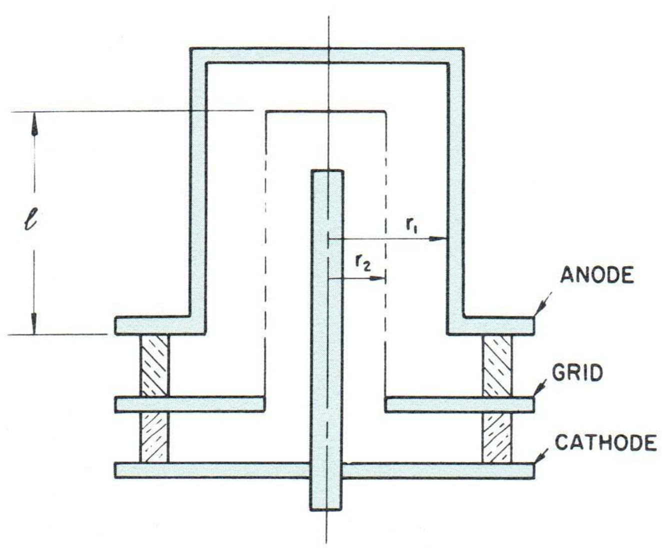


Figure 1 — Typical Basic Cylindrical Tube Structure (1)

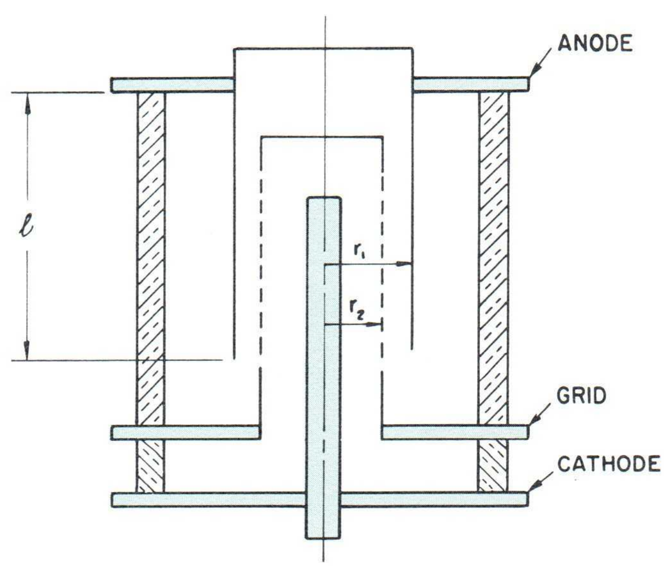


Figure 2 — Typical Basic Cylindrical Tube Structure (2)

cm respectively (mechanical spacing). This gives a $\triangle Cga/Cga$ per equation (2) for a nickel-iron anode of 2×10^{-3}.

The change in frequency is determined by the ratio

$$\frac{\triangle F}{F} = -\frac{1}{2} \frac{\triangle C}{C} \quad (5)$$

Using the above value for $\triangle Cga/Cga$ and a center frequency of 2000 Mc we obtain a $\triangle F$ of plus 2 Mc based on the mechanical spacing, which differs somewhat from the actual electrode spacings when the tube is hot.

Planar Electrode Structure

Figure 3 shows a typical planar tube structure such as the 3CX100A5/7289. The grid-anode capacitance Cga represented in the ratio $\triangle Cga/Cga$ expresses the influence of the anode expansion.

$$\frac{\triangle Cga}{Cga} = -\frac{\triangle S}{S} \quad (6)$$

Substituting $l \alpha \triangle T$ for $\triangle S$ we obtain

$$\frac{\triangle Cga}{Cga} = -\frac{l \alpha \triangle T}{S} \quad (7)$$

Equation (7) shows the change in Cga depends on the distance of the re-entrant anode, the anode material, and the grid anode spacing. Furthermore one can see from this equation that if the distance l is made zero, there is no change in grid-anode spacing with a change in anode temperature and subsequently no change in center frequency. Figures 5 and 6. By making the anode slightly re-entrant or slightly recessed, it is possible to achieve a positive or negative frequency shift, if desired.

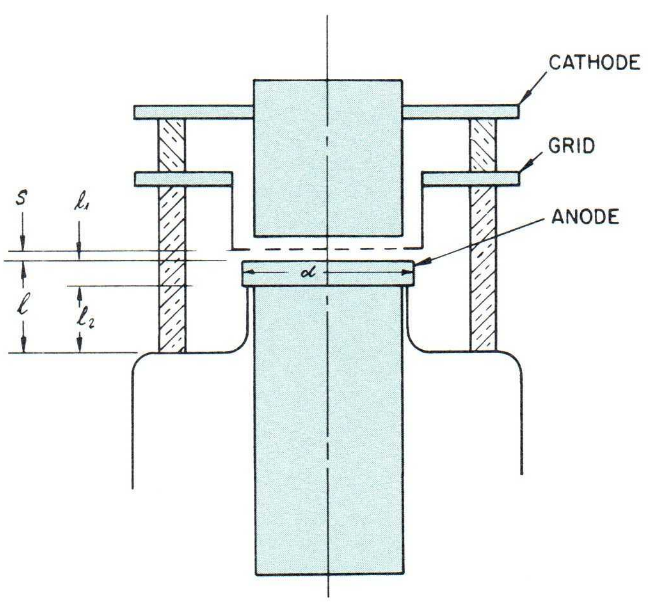


Figure 3—Typical Planar Tube Design of 3CX100A5/7289 Construction

For the tube structure as represented by the 3CX100A5/7289 a frequency shift of 12 Mc and more was observed due to an anode temperature change of 100° C at 2000 Mc. It should be noted that in the above tube type the distance l consists of the distance l_1 and l_2, whereby l_1 is copper and l_2 is nickel-iron. With $l_1 = 0.229$ cm, $l_2 = 0.481$ cm, and $S = 0.061$ cm we obtain per equation (7) for $\triangle Cga/Cga = 1.12 \times 10^{-2}$. If we put this result in equation (5) for a center frequency of 2000 Mc, we obtain a frequency shift of minus 11.2 Mc. Figure 4. If the entire length, l, is of nickel-iron as, for instance, in the 2C39WA tube (See Figure 4), the frequency shift is still 6.5 Mc. For a solid copper anode the shift would be as much as 21 Mc.

Actual and Proposed Applications

A C.W. oscillator operating in the 2200 to 2300 Mc telemetering band, constructed with a conventional 3CX100A5/7289 tube gave the following results when operated intermittently. After a cathode warm-up time of 5 minutes, which is more than adequate, the plate voltage was turned on. In about 1 to 2 minutes the external surface anode temperature rose approximately 75° C and the frequency dropped approximately 10 Mc in the same time. Stable operation, i.e., after no further frequency change was observed, was obtained after 15 to 30 minutes from the time the plate voltage was turned on. This shows, — if we are dealing with continuous operation — that the usual tube is satisfactory after an initial warm-up period. A tube with a modified anode structure as shown in Figure 5 showed an increase in frequency of approximately 1 Mc in the first few seconds after applying the plate voltage. The frequency returned to within a few tens of kilocycles of the original frequency after 15 to 20 seconds and was stable thereafter for the observed period of operation (Figure 7).

If a tube is operated pulsed, oscillator or amplifier, with widely different duty cycles, due to a change in coding, for instance, the plate dissipation changes and, with this, the anode temperature. As shown above the frequency will change unless a tube with the modified anode structure is used.

Certain requirements might call for a very small and light weight power supply not permitting the regulation of the plate voltage. As long as the minimum expected plate voltage is sufficient to give the required minimum power output, a tube with the modified structure will meet the requirements. No change in frequency will be experienced. In one particular application it was found that a variation in plate power input of ±25% did not affect frequency stability.

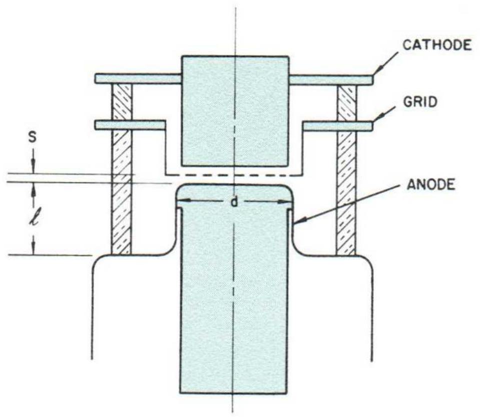


Figure 4 — Typical Planar Tube Design of 2C39WA Construction

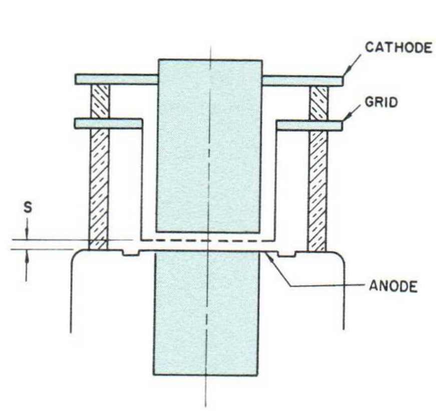


Figure 5 — Planar Tube with Frequency Stable Anode Design as in ML-518 and ML-7855

In microwave relay equipment or other applications, where multichannel switching is required, another problem associated with anode temperature detuning arises. Consider the power output stage which is tuned to resonance at, for instance, 50 channels by a motor driven tuning mechanism. Let's assume we set the tuning for channel 43. The result may be (1), the tuning is optimum for the frequency; (2), the tuning of the cavity and tube is to a slightly higher frequency than the frequency to be amplified; (3), the tuning of the cavity is to a slightly lower frequency than the frequency to be amplified. For the first case the power output will be normal. For the second case the power output will be off as much as 15%, depending on the amount of detuning. Such operation off the resonance peak not only gives a loss of power output but increases the plate dissipation. The increased plate dissipation will cause the anode to lengthen, which increases the grid to plate capacity and lowers the resonance frequency of the cavity and tube. This in turn increases the efficiency and lessens the plate dissipation which stops the anode expansion. In other words the circuit tunes itself to a stable operating point. In the third case, since the circuit is already tuned to a frequency lower than it should be, the increased anode dissipation leads to a further detuning of the stage with still further loss in power output and increased anode dissipation. Circuits operating at less than 1000 Mc have detuned themselves with 3CX100A5/7289 tubes such that the power output fell from 20 watts to less than 5 watts in a few minutes. The cure for this problem is either the use of a low Q broadband circuit, or a tube with a modified anode structure as described above which eliminates this problem.

Conclusion

It has been demonstrated that a tube with a frequency stable anode structure can be made and that this tube must be of planar design when used in UHF circuitry. Futhermore it was shown that tubes constructed with the modified structure, as the ML-518 and ML-7855, operated in actual applications as expected.

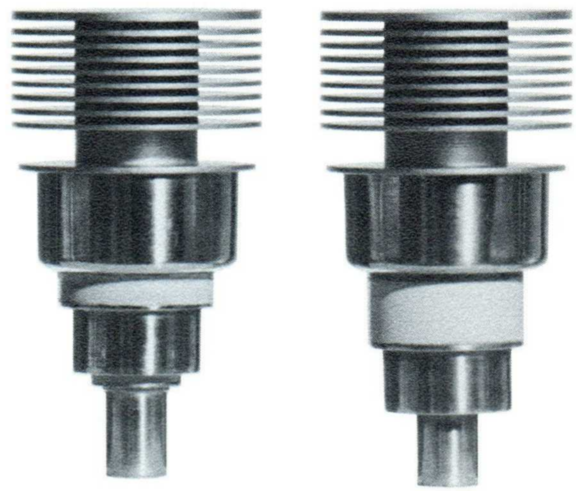


Figure 6 — ML-518 and ML-7855

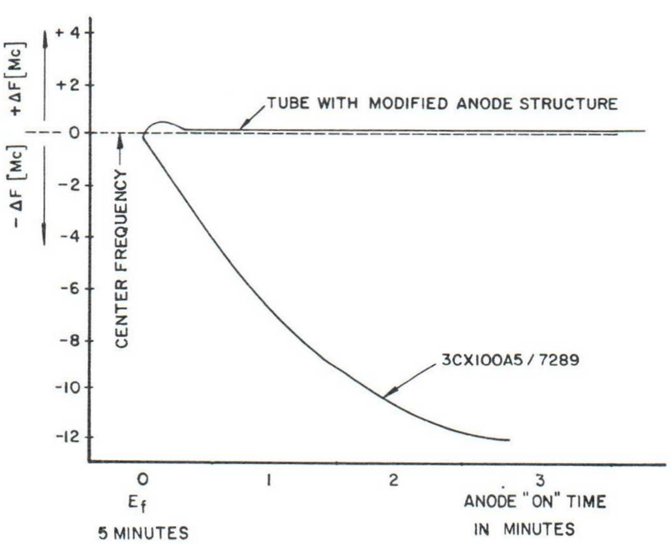
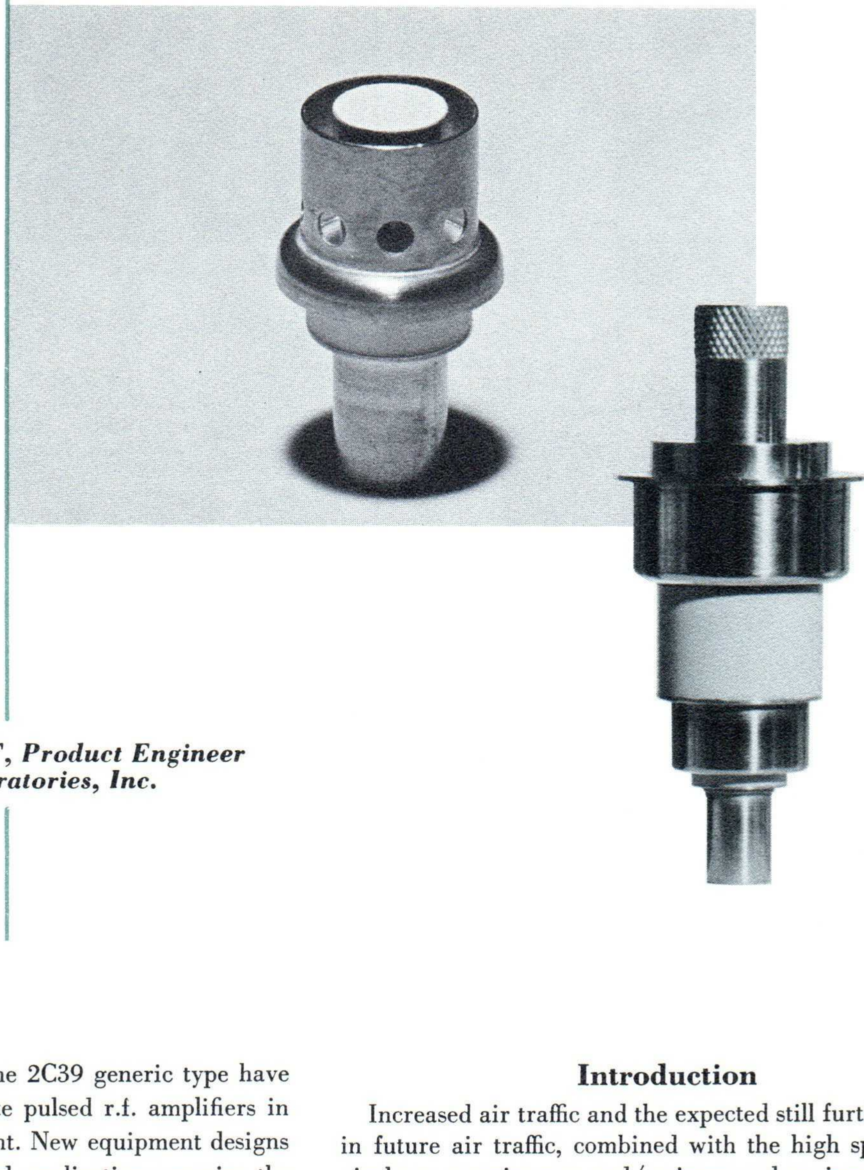


Figure 7 — Frequency Response vs. Time in a particular Oscillator

Phormat Cathode



by ***WERNER BRUNHART, Product Engineer***
The Machlett Laboratories, Inc.

Planar transmitting tubes of the 2C39 generic type have been used extensively as plate pulsed r.f. amplifiers in airborne navigation equipment. New equipment designs for air traffic control and related applications require the use of grid modulation instead of plate modulation. This, in turn, places new requirements on the tubes themselves. Because standard oxide cathodes of the (Ba Sr Ca) CO_3 type could not stand the higher DC plate voltages required for grid modulation, a new cathode matrix type — the Phormat Cathode — was developed by means of using the simultaneous application of the electrolytic and cataphoretic process. Tubes employing this type of cathode are now successfully used in air traffic control and other equipment with a plate voltage of up to 2000 volts DC in grid modulated service.

Introduction

Increased air traffic and the expected still further increase in future air traffic, combined with the high speeds of the airplanes, require new and/or improved equipments for distance measuring (DME) and automatic signaling (Transponder) as well as other navigational aids. The number of the various equipments is such, that weight space and power consumption requirements become of even greater importance than heretofore, especially since airplanes of the commercial airlines and also small private planes are affected. Similar conditions have to be met for equipments used in missile guidance control. The equipment manufacturers have gone so far as to completely transistorize the circuits (except for the transmitter output tube or tubes) to minimize space and weight. The equipments mentioned above

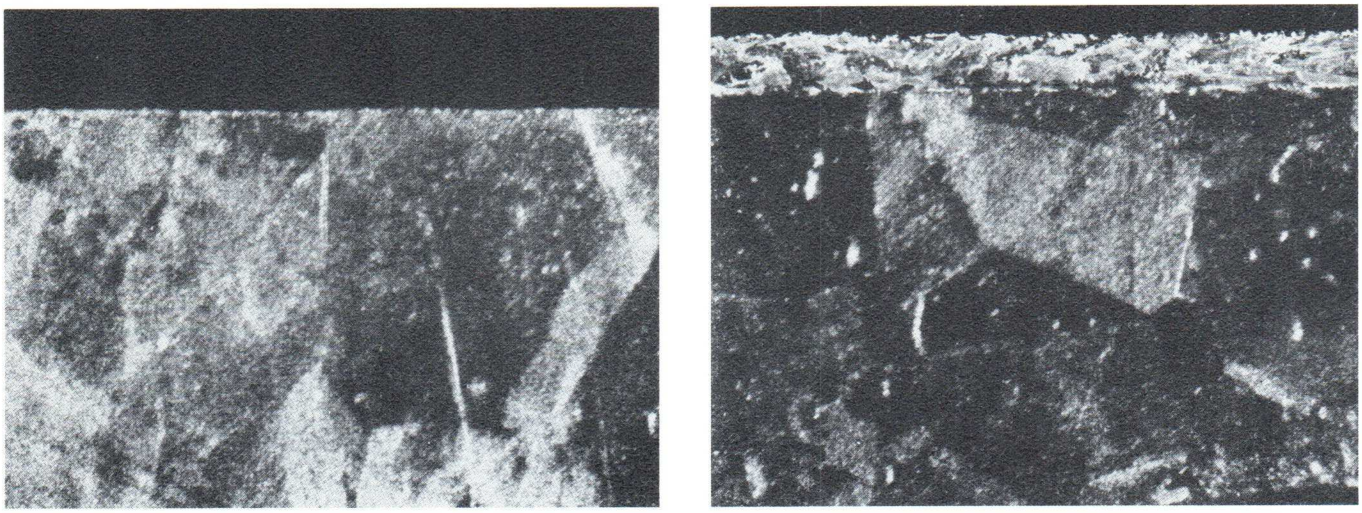


Figure 1 — Sectioned views, standard cathode, left; Phormat cathode, right. Note layered construction of Phormat cathode; this design improves electrical conductivity between coating and base metal and electrical and thermal conductivity of emissive coating. The above views are greatly magnified and show the base cathode metal without the oxide emitter coating.

operate with a pulse code which was, and in some cases still is, provided by plate modulation, requiring a line type or hard tube modulator. These modulator tubes can, in some cases, be replaced by solid state switches; as, for instance, silicon controlled rectifiers, as long as the power requirements are not stringent. For higher power, and depending on the pulse code repetition rate, the requirements are too severe for a solid state switch when used in connection with plate modulation. If, however, grid modulation is used the solid state devices provide adequate and reliable service. Grid modulation on the other hand requires much more from the transmitting tube, especially with respect to holding off higher DC plate voltages. The planar UHF transmitting tubes are usually limited to a plate voltage of 1000 volts DC. The application of still higher voltages has resulted in short life and unreliable operation. The main reason for this limitation rests with the design of the standard oxide coated cathode.

Cathode Development

The conventional oxide cathode used in planar type UHF transmitting tubes consists of a flat nickel disc of about 0.5 cm^2 area, for example on the ML-2C39A, on which is sprayed the emitter coating. This coating consists of a mixture of barium, strontium, and calcium carbonates. During tube processing these carbonates are converted to their respective oxides. The resulting (Ba Sr Ca) O acts as a semiconductor at operating temperatures of about 800° C. "Patch" effects on such cathodes are common. This means that the emitting surface is not homogeneous all over. Under high voltage operation certain small areas tend to spark. Such sparks result in blasting out small cathode areas, resulting in particles of the oxide coating being deposited on neighboring electrodes. The presence of such loose particles makes the tube more susceptive to further sparking.

In order to obtain a cathode which is considerably better with regard to high voltage operation, it is necessary to improve the conductivity between the coating and the base metal as well as the electrical and heat conductivity of the emissive coating. This result can be achieved by using a porous nickel matrix on the base nickel disc and impregnating this matrix by the oxide coating material. Such a cathode has a conductivity metal network extending through the semiconductor coating.

Many different types of such porous matrices have been developed. In one case a porous tungsten disc has been used in which the oxides diffuse to the surface. This type of cathode requires appreciably more heater power and it evaporates excessive amounts of barium from its surface due to its higher operating temperature. Such a cathode is further limited on peak currents required for short pulse operation compared to conventional oxide cathodes. Other types of matrices which have been used consist of (1) application of nickel powder in a binder using a spray gun; (2) sifting nickel powder onto a viscous organic material which has been painted on the base metal surface; (3) mixing the nickel powder and carbonates together and pressing a compact at very high pressures; (4) depositing nickel particles by electrolytic methods; (5) painting with a brush.

The principal problems encountered in the above techniques, as well as in others that have been tried, is reproducibility of pore size and good sintering between particles

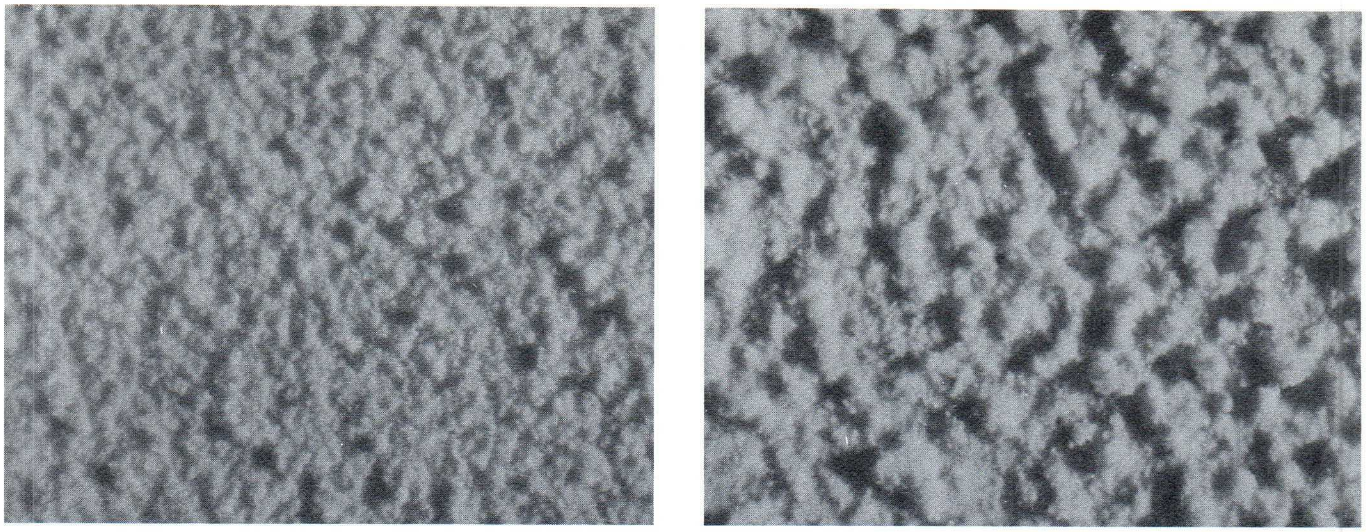


Figure 2 — Top view of standard cathode and Phormat cathode, right, shows porosity of Phormat surface. Porous matrix improves high voltage stability because it inhibits arc development. (Same magnification used for both views).

as well as between nickel particles and the base nickel.

A new method for the application of the matrix was developed which uses the simultaneous application of the electrolytic and cataphoretic processes. The uniformity and reproducibility of the matrix obtained by this new method is good. Height, density, and pore size can be determined by selection of the proper parameters such as temperature of the solution, current density, time, etc. The appearance of the matrix right after the application is black but becomes metallic bright after sintering. It is virtually impossible to remove a finished matrix layer of the Phormat type from the emitter base.* The application of the (Ba Sr Ca) CO_3 into the matrix cathode emitter is done by a very wet spray, resulting in a particle free surface. No special assembly equipment is required other than that used for the standard cathode. Furthermore, the heater power for the Phormat Cathode is the same as the one required by the standard cathode.

Application of Phormat Cathode

To date a number of our tube types have been made with the Phormat Cathode and successfully used in circuits using grid modulation. The ML-7698 and the ML-7815 are rated at a plate voltage of 2000 volts DC for grid modulated service. Both tube types were tested in a grid modulated amplifier circuit in the laboratory with a plate voltage of 3000 Vdc. Other tests performed using the ML-7815 tubes as the switch in a hard tube modulator circuit proved the superiority of the Phormat Cathode as compared to standard cathodes. Plate voltages of up to 7000 volts DC and more were applied to tubes having standard and Phormat cathodes. This corresponds to a mean field gradient of 135 kV/cm between the grid and anode of the tubes. While the standard cathodes were almost completely destroyed, the Phormat cathode showed only a few arc marks. This was further indicated by the marked improvement of operational stability achieved with the Phormat Cathodes.

The above tests indicated that the rating of 2000 volts DC plate voltage is safe and conservative. This was further substantiated by extensive laboratory and field life testing in airborne equipment, resulting in several thousand hours' tube life. Tests are presently being made with a tube type operating at a DC plate voltage of 3200 volts with grid modulation. Another application of the Phormat Cathode is in our ML-DP30 tube type which has a tentative rating of 8 kV.

Conclusion

The combination of electrolytic and cataphoretic deposition of a porous nickel matrix cathode was used for the development of the Phormat Cathode. This type cathode was successfully and reliably used in tubes such as the ML-7698 and ML-7815 in grid modulated circuits at higher DC plate voltages than were hitherto possible with the standard cathodes.

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*For further information on the development of the "Phormat Cathode" see the paper by: Peter F. Varadi and Kitty Ettre; Simultaneous cataphoretic and electrolytic desposition of nickel for plated cathode of reliable electron tubes. (To be published).

Mounting

Contacts to anode, grid, cathode and heater terminals should be made by means of spring fingers or spring collets bearing on the cylindrical surfaces within the dimensional limits specified on the tube outline under "Dimensions for Electrode Contact Area." If the employed connectors do not provide multiple contacts to the cylindrical contact surfaces, concentration of r-f charging current will result in a subsequent loss of power output. The tube, when in the socket or cavity, should seat against the area designated as tube stop (reference surface). The tube should not be seated or stopped by any other surfaces. When the tube must be clamped in its socket to prevent loosening due to shock and vibration, clamp pressure should only be applied to the anode flange (grid flange of the 6442 and 6771). Rigid clamping on the electrode terminals should be avoided. It has been found that such rigid clamping connectors will distort the tube terminal and damage the adjacent metal-to-ceramic or metal-to-glass seal. Also, set screw contact devices can result in a fractured tube, unless they are designed such that they distribute the pressure uniformly and without any distorting effects. In case circuit considerations demand that contacts, as grid resistors, be directly soldered to the tube terminal, great care must be taken not to damage the metal-to-ceramic (glass) seal due to thermal shock.

Cooling

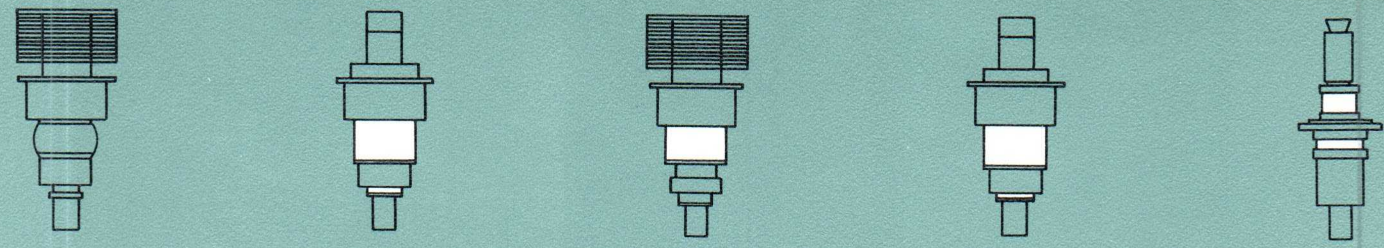
Machlett U.H.F. tubes are designed to permit high temperature operation up to the envelope temperature indicated for the individual tube type under consideration. However, performance and long-term reliability of any component is enhanced when it is kept as cool as possible; therefore, it is recommended to cool all seals well below the specified maximum temperature where long tube life and great reliability is of importance.

Cooling can be by means of conduction, convection and/or forced-air cooling. When forced-air is employed, it is recommended that additional air flow, apart from that flowing through the radiator, be used to cool the tube envelope and other tube terminals. If only convection cooling is employed, ample free space around the tube anode radiator or anode knob must be provided for the circulation of the air. Conduction cooling is usually always provided to some extent, depending on circuit design, through the contact arrangements at the tube terminals. However, it must be pointed out that contact fingers usually provide poor heat conduction; measurements have shown them to be as much as 50°C cooler than the electrode terminals themselves. If the bulk of the anode dissipation is to be dissipated in a heatsink, proper care must be taken to provide a suitable heat-flow path between the heatsink and the tube anode. Some of the tube types can be provided with special heatsink adapter (see page 90), which provide a heat-flow path with high thermal conductivity. The heatsink, as such, should be designed to act as a constant temperature device; that is, to prevent any increase in temperature by dissipating the heat beyond the device, as such. In many cases the equipment chassis, plate line or tube cavity is such a heatsink. In most cases the heatsink adapter must be insulated electrically from the heatsink. Mica, high aluminum oxides and beryllium oxide, besides other insulating materials, serve quite readily such a purpose. The thermal conductivity of these insulating materials varies considerably, and therefore, the choice of the material will depend mainly on the plate dissipation for the particular application. In applications which call only for low anode dissipation, as is the case with many pulse applications, not the anode terminal, but the cathode terminal is usually the hottest tube part. Depending on the operation, a reduction in heater voltage might be indicated (see "Heater Voltage") rather than provide additional cooling to that particular electrode.

In all new applications it is suggested that the envelope temperature be measured if the tube is used close to the upper limit of the specifications and always in cases not using forced-air cooling. Tempilaq paint, made by Tempil Corporation, 132 West 22 Street, New York 11, New York, or Temp-Plate stickers, made by Pyrodyne, Incorporated, 11876 Wilshire Boulevard, Los Angeles 25, California, serve as a temperature measuring means and are usually the most practical technique.

Heater Voltage

The heater voltage is a very important factor with regard to tube life. No general statement as to the optimum heater voltage can be made. There are many applications where a lower heater voltage than the nominal should be used to obtain the longest possible tube life. In addition, in the frequency range where these tubes are normally used, the electron transit time is not necessarily small with respect to the period of oscillation. This results in a decrease in power output and operating efficiency with an increase in frequency and the bombardment and heating of the cathode by electrons from the grid region, which can be severe enough to result in short tube life and/or erratic operation. The transit time heating effect is a function of frequency, grid current, grid bias plate voltage and current (duty cycle if applicable), and circuit design and adjustment. There is an optimum heater voltage which will maintain the cathode at the correct operating temperature for a particular set of op-



erating conditions. If the back-heating is appreciable, it will be necessary to start dynamic operation of the tube at the normal heater voltage, followed by a reduction of the heater voltage to the optimum value. For long life and reliable tube operation, it is recommended that the heater voltage not vary more than $\pm 2\%$ from the optimum. A maximum variation of $\pm 5\%$ from optimum is permitted.

For applications above 500 Mc and unusual applications it is suggested that the Machlett Engineering Department be consulted for optimum heater voltage.

Plate Surge-Limiting Impedance

In the U.H.F. tubes, as discussed here, with the very closely spaced electrodes, extremely high voltage gradients occur, even with moderate tube operating voltages. Any tube flash-arcing may be destructive. The plate supply should be designed such that its impedance limits the short-circuit current within five to ten times the forward current. For pulsed operation the supply impedance should be designed such that the short-circuit current does not exceed ten times the maximum ratings for pulsed operation. Such operation is particularly necessary where d.c. heater excitation is used and the heater voltage is used to obtain a d.c. grid bias. Under such conditions, surge currents can get to the negative plate voltage supply lead only through the heater winding and may cause the shorting of the heater element unless provisions are made for limiting the current. Failure of tubes due to internal flash-arcs is much more prevalent when the circuit is not tuned to optimum conditions. Even though laboratory tests indicate no such protection is needed, poor circuit adjustment in the field may result in shortened tube life.

Provision for Circuit Tuning

With high-frequency circuits a very small motion of a tuning plunger may throw the tube out of resonance and result in high plate current and/or excessive anode dissipation. If the tube is operated at or close to maximum ratings, it is suggested that provision be made for tune up at reduced plate voltage in any circuit where the above conditions exist.

Self-Biasing Operation

In general, for CW operation, an RC bias should be in the cathode circuit such that with normal d.c. plate voltage and no grid drive the plate current does not exceed the maximum rated cathode current. If grid resistor biasing is used only, special care must be taken to protect the tube against loss of excitation; otherwise, excessive plate currents may damage the cathode. Cathode biasing, being unaffected by excitation loss, offers additional protection against plate surge currents, as discussed above.

For plate-pulsed operation a bypassed or unbypassed grid resistor is usually satisfactory, provided suitable plate surge-limiting impedance is used. Grid-pulsed operation always requires cathode biasing and/or external bias.

Determination of Proper Grid Drive

The drive requirement, as shown in typical operation conditions or as required in actual applications, is always considerably more than is normally calculated for typical driving power input. This is necessary to permit a range for adjustment and also to provide for the losses in the grid and coupling circuits. This consideration is particularly important at the high frequencies where circuit losses, radiation losses and transit-time losses increase.

In grounded-cathode stages (grid-drive circuit) the power output tends to saturate and may even decrease as the grid drive is increased. In grid-separation circuits (cathode-drive circuits) driver power output and the developed r-f power output act in series to supply the load circuit. Therefore, increased power output is always obtainable from increased grid drive. It is important to recognize this difference and not to overdrive in grid-separation amplifiers, since this results in high grid current, increased backheating of the cathode and distortion of the r-f signals due to the heavy loading of the grid signal in the positive grid region. This usually results in reduced tube life.

For tubes operated grid pulsed, and for that matter, also in many other cases, the limiting factor is very often not the anode dissipation and cathode emission capability, but the grid dissipation. This is especially important if higher duty cycles for grid pulsing and also plate pulsing are employed. Too high grid dissipation will always result in short tube life and/or erratic operation.

Unusual Applications

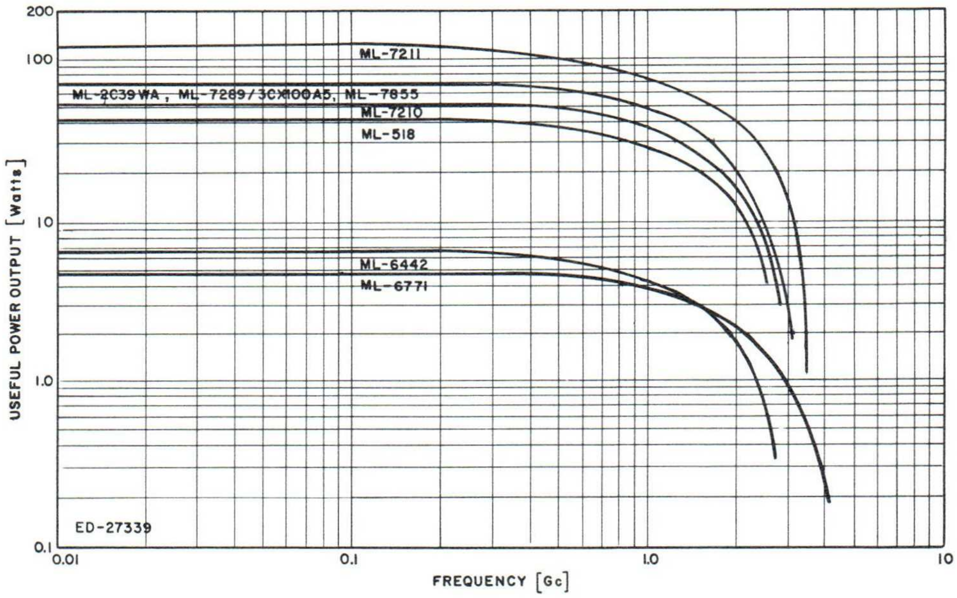
If conditions are such that the ratings given on the individual tube specification sheets do not apply, additional information may be obtained from the Machlett Engineering Department.

UHF Planar Triode Application Data . . . Power Output vs Frequency

CW

Approximate Power Output Of Various Planar Triodes

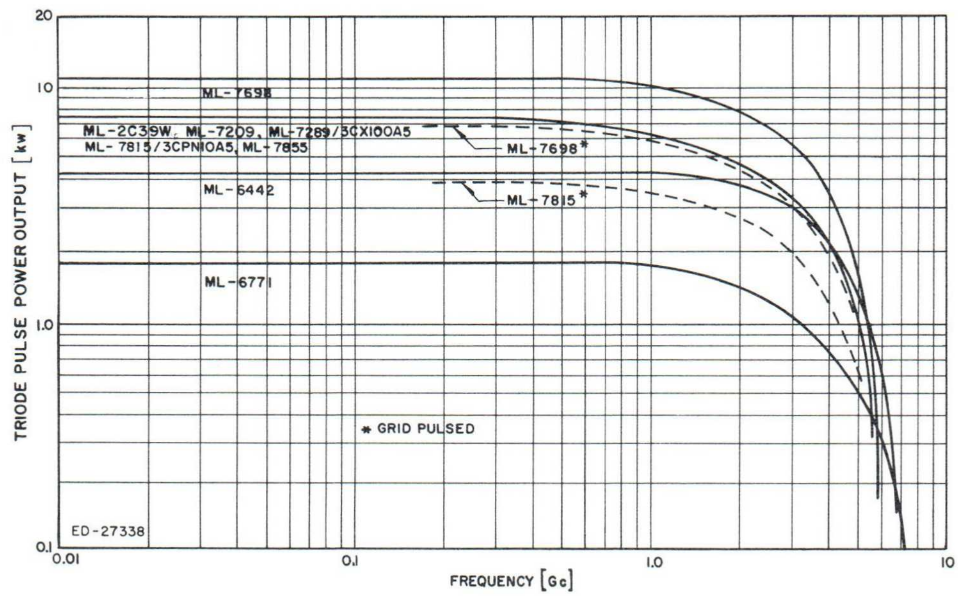
ML-2C39WA, ML-518, ML-6442, ML-6771, ML-7210, ML-7211, ML-7855, ML-7289/3CX100A5



Pulsed

Approximate Pulse Power Output Of Various Planar Triodes, Plate-Pulsed

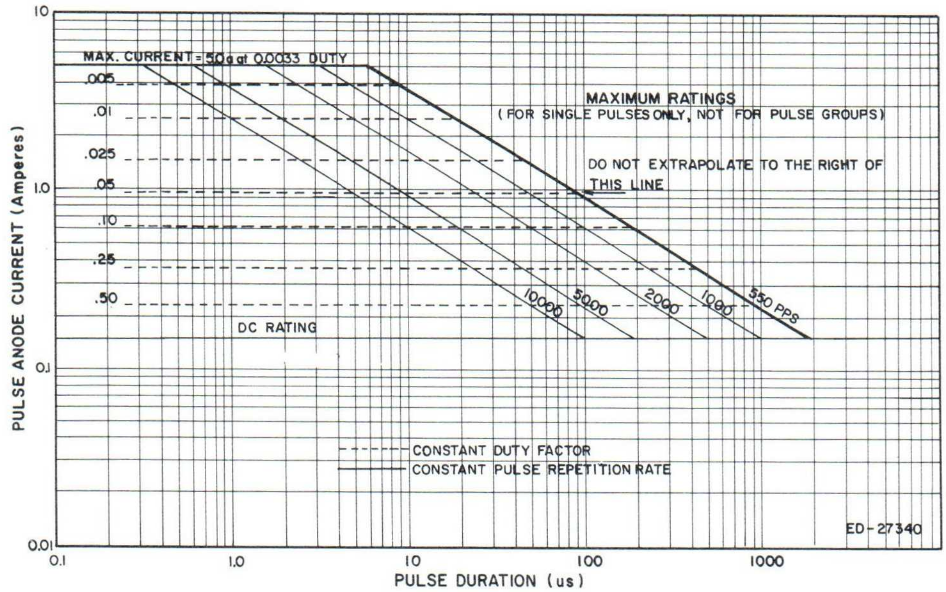
ML-2C39WA, ML-6442, ML-6771, ML-7209, ML-7698, ML-7855, ML-7289/3CX100A5, ML-7815/3CPN10A5



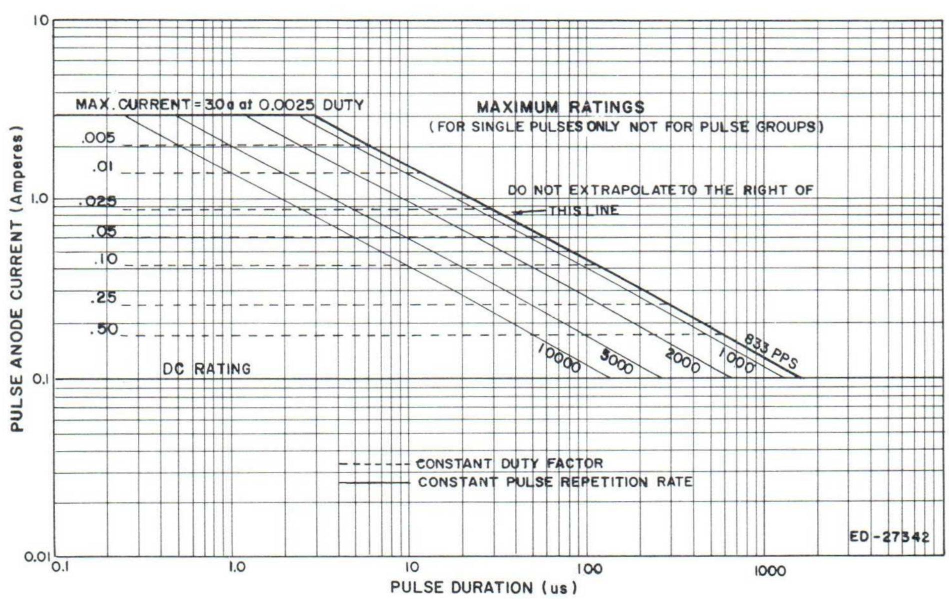
The above curves, and those on pages 19 and 20, have been drawn to aid in the selection of tubes but are not, however, a clear-cut guide to performance capability. In all cases the final choice should be based on the complete ratings and characteristics for the types under consideration. Additional information on any particular application may be obtained from The Machlett Engineering Department, at which time the limitations of these charts can be taken into account.

UHF Planar Triode Application Data . . . Anode Current vs Pulse Duration

Pulse Anode Current vs Pulse Duration
ML-7698



Pulse Anode Current vs Pulse Duration
ML-2C39WA, ML-518, ML-7289/3CX100A5, ML-7855



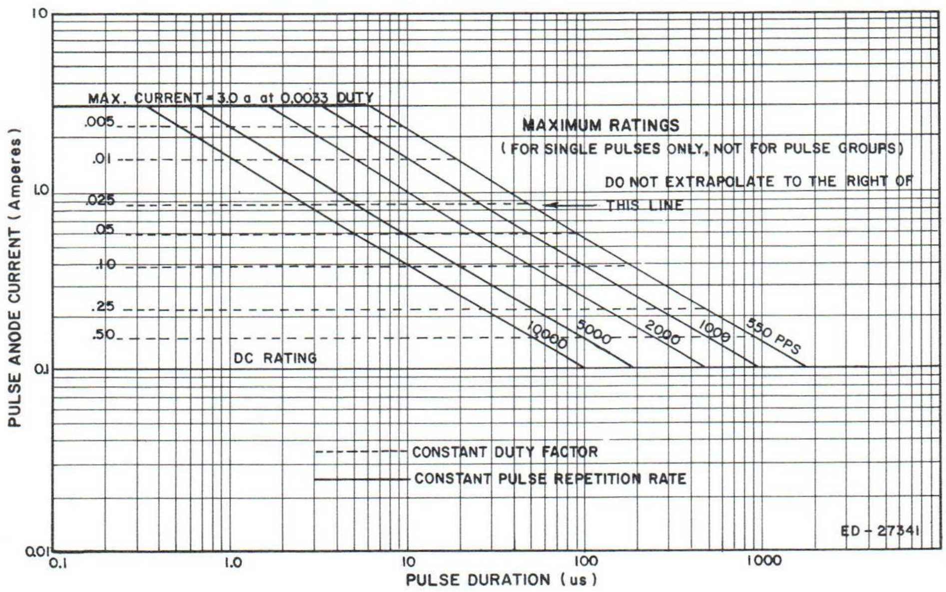
For pulsed applications it is important to calculate and control the grid dissipation very accurately. In many instances, this will be the limiting factor, rather than the plate dissipation and cathode emission capability.

Pulsed

UHF Planar Triode Application Data . . . Anode Current vs Pulse Duration

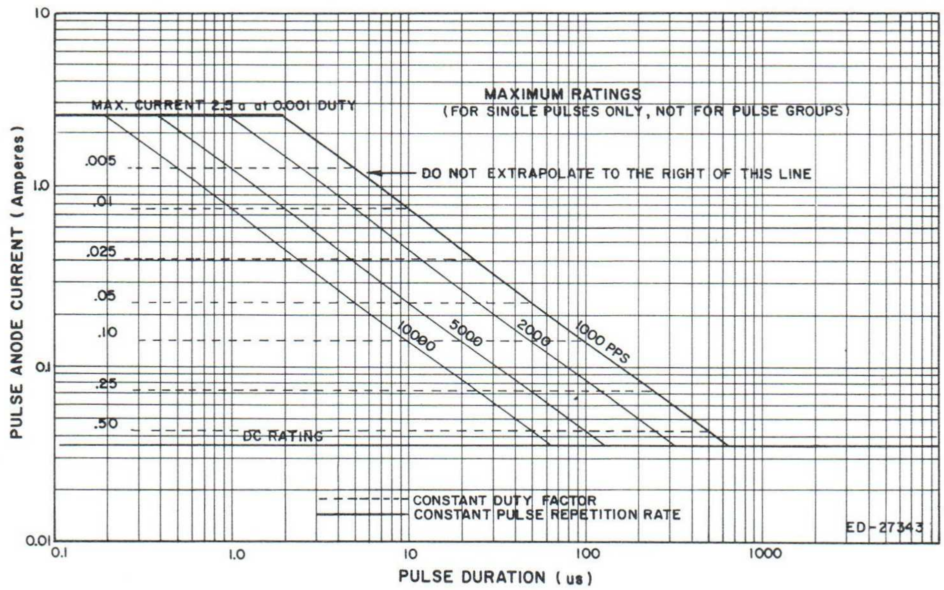
Pulsed

Pulse Anode Current vs Pulse Duration
ML-7815/3CPN10A5 & ML-7209



Pulsed

Pulse Anode Current vs Pulse Duration
ML-6442



For pulsed applications it is important to calculate and control the grid dissipation very accurately. In many instances, this will be the limiting factor, rather than the plate dissipation and cathode emission capability.

Cavity drawings shown on this and the next two pages illustrate the tube/cavity relationship and provide a visualization of the tube/cavity contact configuration.* These cavity types, JAN 160 (cw cavity) and JAN 279 (pulsed cavity) are used by The Machlett Laboratories for engineering design tests as well as for production testing as called for by the applicable military specifications. Typical usage of the JAN 160† cavity is described below.

Power oscillation . . . life tests:

CW Power oscillation at 2.5Gc. Tubes are oscillated under power to determine that the tube performs well beyond minimum power ouput, and also performance as an oscillator.

Life test measurements at .5 and 2.0Gc under CW conditions.

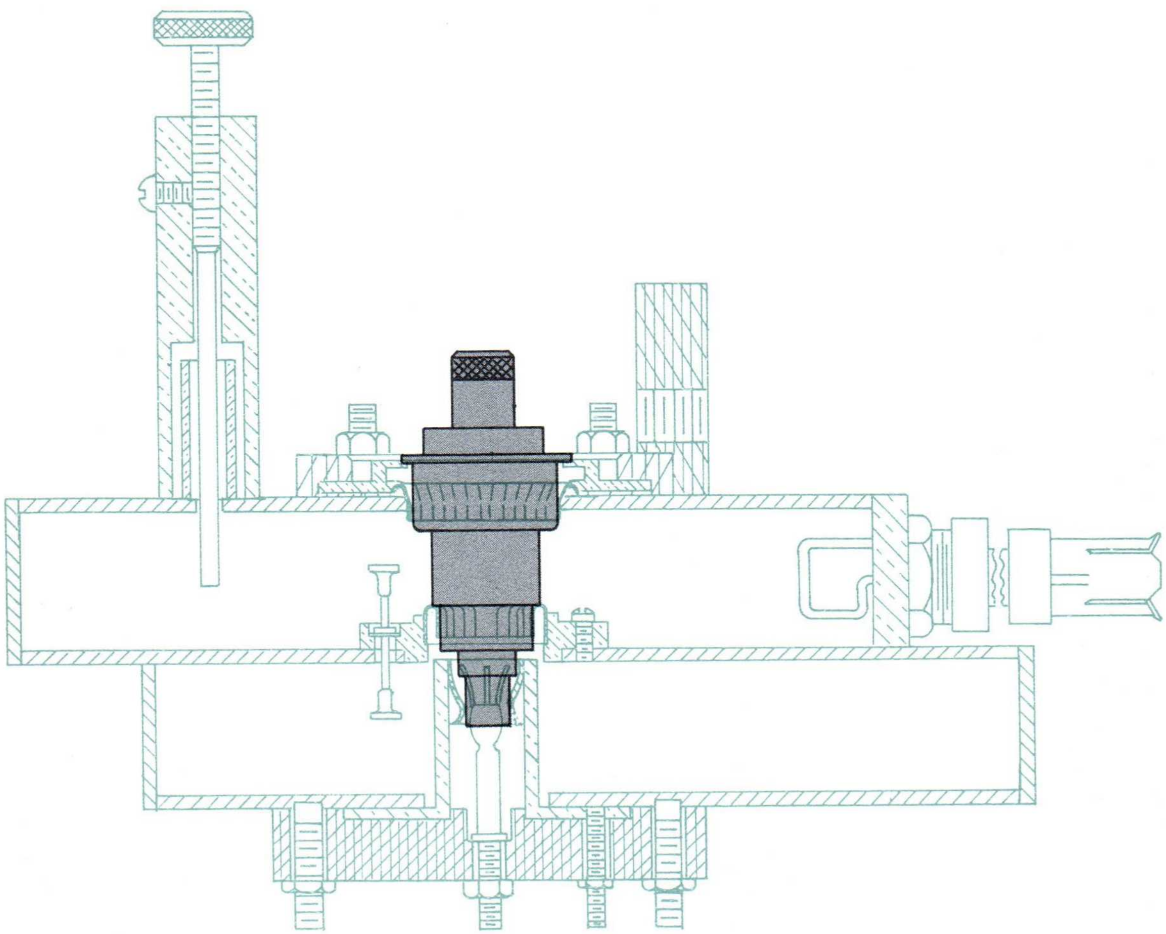
(Amplifying characteristics and capabilities of tube are tested in other cavities.)

Static characteristic tests:

Static characteristic tests, performed on Machlett planar triodes include: heater current, electrical insulation, cut-off voltages, inter-electrode capacitances, emission at various cathode voltages (good emission at reduced Ef is the sign of an active cathode surface and insures good emission at higher voltages); 4500 usec emission test (to determine quality of cathode activity under extremely high loading); positive grid current division test to determine electrode parallelism and provide indication of grid-anode spacings); to check fit of tube to expected static characteristics.

* Tube contact data information is found on Page 33.

† Various cavity configurations are used for the performance of these tests.



JAN Pulsed Cavity

Cold resonance test, an extremely stringent physical test in which the tube, not operated, is inserted "cold" into the cavity to determine accuracy of electrode spacing within tube. The tube, acting as a capacitance, will allow cavity resonance only if it is within the very small range of tolerance allowed. Actual tube shapes, also, are monitored by this test.

It may be appropriate here to mention other tests performed on Machlett planar triodes; these include mechanical, high voltage, and high temperature life tests. These tests do not involve JAN cavities.

Mechanical

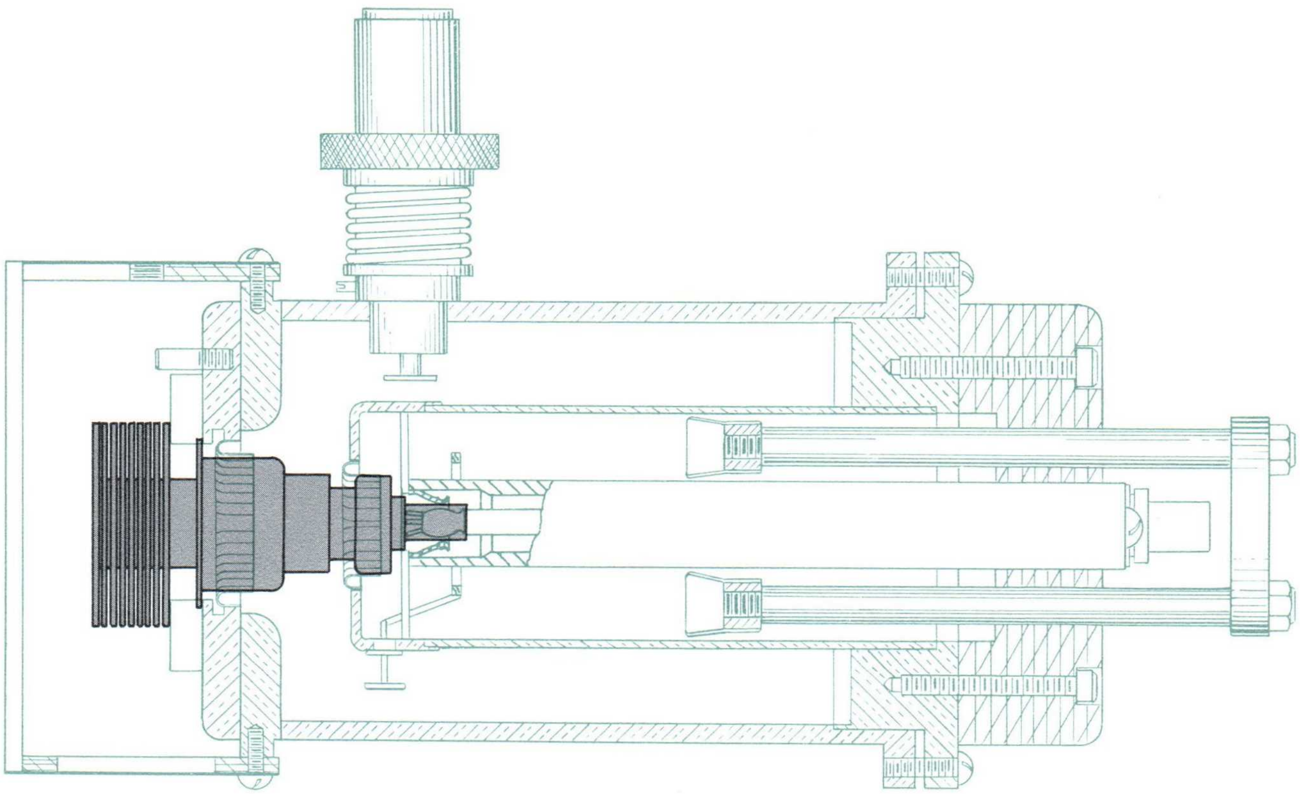
Tubes are tested at 500 and at 2000 cps under 10g and 5g loads respectively. Tubes must be free of resonant periods. Such examinations as these are used to demonstrate the worthiness of the tubes for the high stress activity of the missile environment. So, too, are the "high g" shock tests wherein tubes are tested at 400g acceleration for 1 millisecond and at 60g acceleration (and higher) for 11 milliseconds.

High Voltage Breakdown

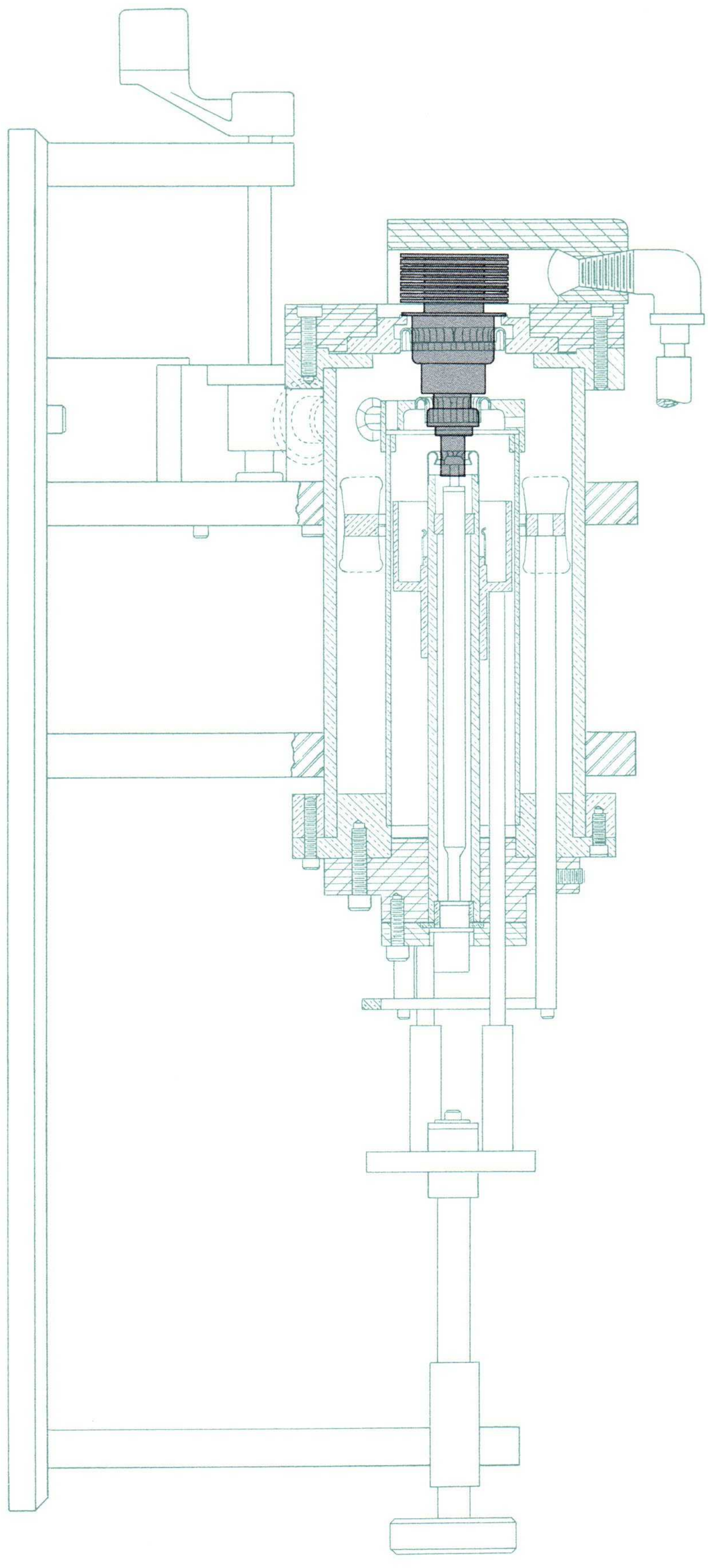
Tubes are tested in accordance with current military specifications to assure reliable high altitude performance.

Elevated Temperature Life Tests

Tubes are life tested under a minimum ambient temperature of 250°C. Machlett ceramic envelope tubes are rated at 300°C.



JAN CW Cavity



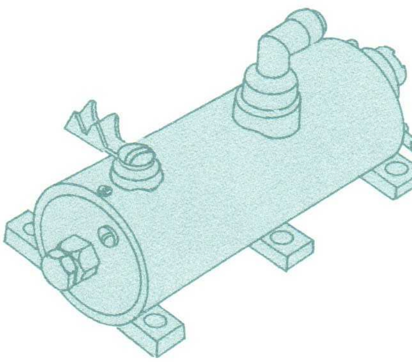
JAN CW Cavity

CAVITIES

In the following section a partial summary of cavities and sockets is given to show availability from several manufacturers. This listing is by no means complete and is intended only to show some typical units available.

ACF Electronics Division, ACF Industries, Paramus, New Jersey

"S" Band and "C" Band plate pulsed oscillator cavities are available from ACF Electronics Division. These cavities employ the ML-6442 (& ML-471) and ML-6771, respectively.



"S"-Band Plate Pulsed Oscillator
Model 331

Frequency Range	2800 — 3000 mc
Peak Power Output	1.5 kw min.
Pulse Drive	2.2-kv @ 2.4 amps nominal
Filament	6.3 v @ 0.9 amps nominal
Duty	0.001 max.
Pulse Width	2 usec max.
Vibration	15 g 20 — 2000 cycles
Shock	70 g while operating (frequency shift 1 mc max.)
Temperature	±4.5 mc drift; −50°C to +100°C
Tube	ML-6442
Size	Approx. 5½" Long, 1½" Diam excluding connectors
Weight	12 oz. max.

Remarks

1. Unit can be modified for any 200 mc tuning range from 2600-3200 mc.
2. Frequency range can be extended to 300 mc with an output of 1.0 kw minimum.
3. Duty cycle can be increased to 0.0016 with slight reduction in tube life.
4. Power output can be increased to 2 kw min. by increasing drive to 3.0 kv at 2.5 amps.

"C"-Band Plate Pulsed Oscillator
Model 338

Frequency	5400 — 5900 mcs
Peak Power Output	1.5 kw min. (200 mc tuning range) 1.0 kw min. (500 mc tuning range)
Pulse Width	0.4 to 1.0 usec
Duty Cycle	0.001
Peak Anode Voltage	2.5 kv
Peak Anode Current	2.5 amps (nominal)
Filament Power	6.3 V @ 570 ma (nominal)
Frequency Pulling	Less than ±2.5 mcs for 1.5 VSWR All Phases
Frequency Pushing	Less than 5 kc/peak ma
Output Connector	TNC Female 50 ohms
Temperature Coefficient	±40 kc per °C
Vibration	20 g 20-2000 cps (5% max. amplitude jitter)
Shock	50 g 3 Planes
Size	4" x 2⅛" x 2" (excluding connector)
Weight	20 oz. (max.)
Mounting	Any Position

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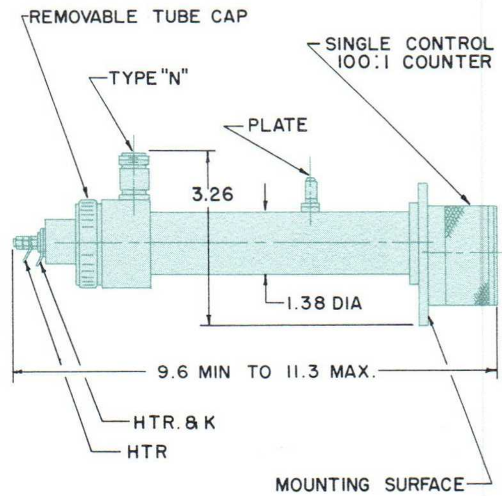
Amerac Company, Beverly, Massachusetts

Amerac cavities are available for frequency ranges from 900 mc to 3800 mc. Machlett types ML-6442, ML-2C39A and ML-7209 may be employed in the Amerac units.

Model	Range	Type of Operation	Cavity Mode	Power	Duty Cycle	Pulse Width μsec	Outline Fig.
195-Series 195-6, 7, 8, 9, 10, 11, 12, 13 Ex: 195-10 for 2800 to 3000 mcs	2000 to 3600 mc in 200 mc increments	Pulse	¾	2.0 kw	.001	.3-2.0	1
500-Series 500-6, 7, 8, 9, 10, 11	2000 to 3200 mc in 200 mc increments	CW	¾	100 mw	—	—	2
501-Series 501-6, 7, 8, 9, 10, 11	2000 to 3200 mc in 200 mc increments	Pulse	¾	2.0 kw	.001	.3-2.0	2
502-and even nos. 502-12, 504-13, 506-14, 508-15, 508-16	3200 to 4200 mc in 200 mc increments	CW	¾	100 mw	—	—	2
503-and odd nos. 503-12, 505-13, 507-14, 509-15, 509-16, 509-17 509-18 509-19	3200 to 4400 mc in 200 mc increments 4400 to 4500 mc 4500 to 4600 mc	Pulse	¾	2.0 kw	.001	.3-2.0	2

Figure 1 195 Series Cavity ML-6442



Model	From	To	Type	Cavity Mode	Power	Duty Cycle	Pulse Width μsec.	Outline Fig.
600	900	1050	CW	¼	5 Watts	—	—	3
601	900	1050	Pulse	¼	2.0 KW	.002	.5-5.0	3
602	1000	1200	CW	¼	5 Watts	—	—	3
603	1000	1200	Pulse	¼	2.0 KW	.002	.5-5.0	3
604	1150	1300	CW	¼	5 Watts	—	—	3
605	1150	1300	Pulse	¼	2.0 KW	.002	.5-5.0	3
606	1250	1500	CW	¼	5 Watts	—	—	3
607	1250	1500	Pulse	¼	2.0 KW	.002	.5-5.0	3
608	1450	1700	CW	¼	5 Watts	—	—	3
609	1450	1700	Pulse	¼	2.0 KW	.002	.5-5.0	3

Figure 2 500 Series Cavity ML-6442

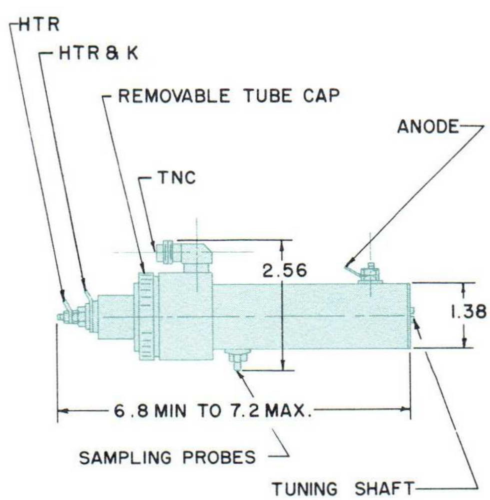
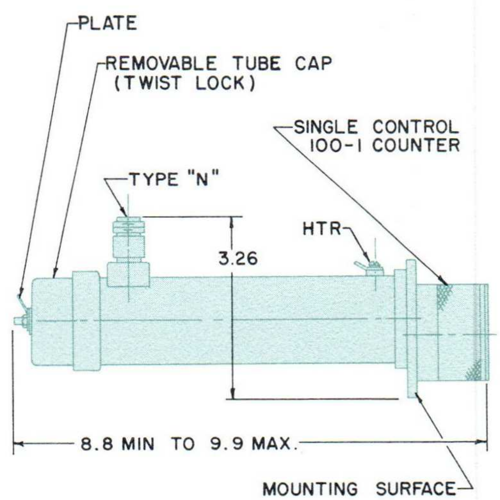


Figure 3 600 Series Cavity ML-2C39A (600, 02, 04, 06, 08) ML-7209 (601, 03, 05, 07, 09)



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Applied Microwave Laboratory, Inc. Wakefield, Massachusetts

A partial listing of cavities available for Machlett Tubes follows. These cavities represent a general coverage of the four primary Frequency bands.

UHF Band

Tube	Cavity	Typical Frequency MC	Power Output	Tube	Cavity	Typical Frequency MC	Power Output
*ML-7289	U2100A	900	25 watts CW	ML-7209	U2100B	500	4 kw @ 0.001 Duty
ML-6442	U2020A	500	3 watts CW	ML-6442	U2020B	500	3 kw @ 0.001 Duty

L Band

Tube	Cavity	Typical Frequency MC	Power Output	Tube	Cavity	Typical Frequency MC	Power Output
*ML-7289	L2120A	1700	15 watts CW	ML-7815**	L2115C**	1100	750 watts @ 0.006 Duty
ML-6442	L2020B	1500	2.5 kw @ 0.001 Duty	ML-6442	L2020A	1000	3 watts CW

S Band

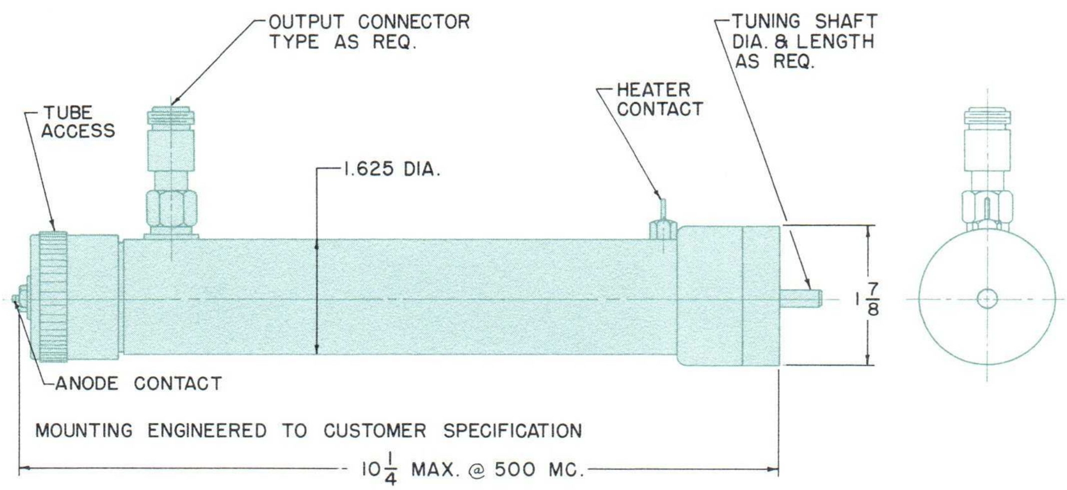
Tube	Cavity	Typical Frequency MC	Power Output	Tube	Cavity	Typical Frequency MC	Power Output
*ML-7289	S2120A	2300	15 watts CW	ML-7698†	S2140B	2800	1 kw @ 0.01 Duty
ML-6771	S2070A	3500	100 MW CW	ML-6442	S2000B	3000	2 kw @ 0.001 Duty

C Band

Tube	Cavity	Typical Frequency MC	Power Output	Tube	Cavity	Typical Frequency MC	Power Output
ML-6771	C2060A	4165	100 MW CW	ML-6442	C2010B	4225	1.5 kw @ 0.001 Duty
ML-6771	C2215B	5000	3 watts @ 0.04 Duty	ML-6771	C2060B	5400	1.0 kw @ 0.001 Duty

*Also branded ML-7289/3CX100A5
**Grid Pulsed
†ML-7698 with radiator

CAVITY OSCILLATOR—2100



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JVM Division, Fidelitone Microwave, Inc. Chicago, Illinois

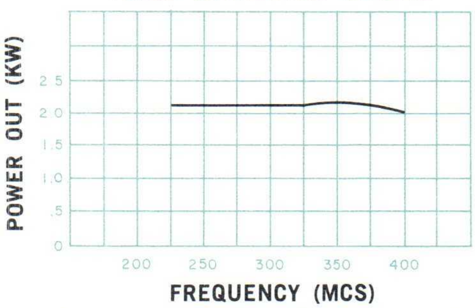
Mercury "10" cavities are available for the most commonly used frequency ranges, and may be modified to prototype needs.

JVM cavities are available for Machlett planar triodes as listed below.

TUBE TYPE	TYPE OPERATION	OSCILLATOR GRID SEPAR.	OSCILLATOR RE-ENTRANT	AMPLIFIER	DOUBLER	TRIPLER
ML-6442	C.W. P.	8302- 7440-	9162- 9126-	8303- 7451-	8304-( )D 7448-( )D	8304-( )T 7448-( )T
ML-6771	C.W. P.	7454-	9163- 9248-	7457-	7460-( )D	7460-( )T
ML-2C39A	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-2C39WA	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-2C41	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-7209	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-7210	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-7289/ 3CX100A5	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-7698	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T
ML-7815/ 3CPN10A5	C.W. P.	8010- 9291-	9164- 9225-	7801-	8062-( )D	8062-( )T

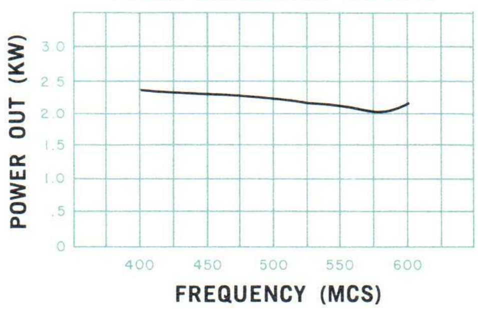
Special Application Performance Charts

D-7600-1
PULSE OSCILLATOR ML-6442



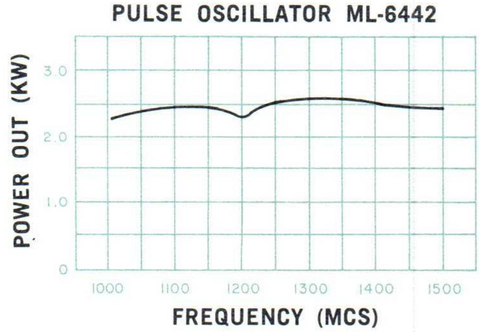
B+ .... 3.0 KV IB .... 2.5 AMP
FIL .... 6.3 VAC

D-7600-2
PULSE OSCILLATOR ML-6442



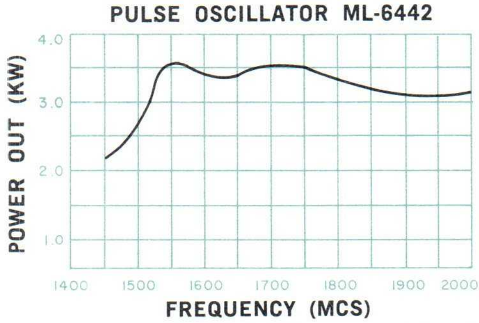
B+ .... 3.0 KV IB .... 2.5 AMP
FIL .... 6.3 VAC

D-8264-A
PULSE OSCILLATOR ML-6442



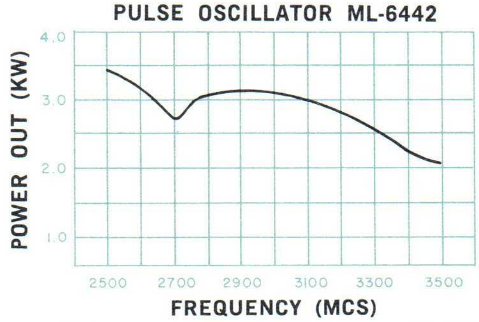
B+ .... 3.0 KV IB .... 2.5 AMP
FIL .... 6.3 VAC

D-8264-B
PULSE OSCILLATOR ML-6442



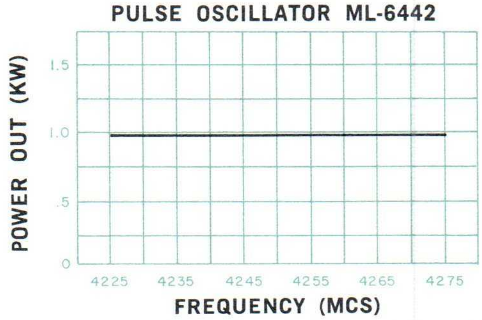
B+ .... 3.0 KV IB .... 2.5 AMP
FIL .... 6.3 VAC

D-8265
PULSE OSCILLATOR ML-6442



B+ .... 3.0 KV IB .... 2.5 AMP
FIL .... 6.3 VAC

D-9119
PULSE OSCILLATOR ML-6442



B+ .... 3.0 KV PULSE WIDTH . . .02
IB .... 2.5 AMP usec @ 50% Pt.
FIL .... 5.7 VAC DUTY CYCLE . . .001
MAX. LOAD VSWR 1.5 BIAS .... GRID

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Microwave Cavity Laboratories, Melrose Park, Illinois

Standard cavities are available for either narrow (Series N) or extended tuning range (Series E). Series N tuning range is minimum of 10%; Series E units can be designed to tune to much greater ranges. Microwave Cavity Laboratories' cavities are available for Machlett tube types as listed below.

	Application	Tube Type	Order by Series—Model No. Series Number	Model Number	Standard Operating Conditions B+ VDC	Ib ma	Ef V	If a	Pin mw
AMPLIFIER, CW	Med. Power	ML-6771	2000-	1 Thru 25	250	20	5.7	0.6	100
	Med. Power	ML-6442	2001-	1 Thru 21	300	22	6.3	0.9	200
	Med. Power	ML-7289/3CX100A5	2002-	1 Thru 21	900	90	6.0	1.0	2000
DOUBLER, CW	Med. Power	ML-6771	5000-	1 Thru 25	250	20	5.7	0.6	100
	Med. Power	ML-6442	5001-	1 Thru 21	300	20	6.3	0.9	200
	Med. Power	ML-7289/3CX100A5	5002-	1 Thru 21	900 Ec=30	90	6.0	1.0	2000
TRIPLER, CW	Med. Power	ML-6771	5003-	1 Thru 25	250	20	5.7	0.6	100
	Med. Power	ML-6442	5004-	1 Thru 21	300	20	6.3	0.9	200
	Med. Power	ML-7289/3CX100A5	5005-	1 Thru 21	900 Ec=30	90	6.0	1.0	2000
OSCILLATOR, CW	Med. Power	ML-6771	6001-	1 Thru 16	250	20	5.7	0.6	—
			*7001-	17 Thru 28	250	25			
	Med. Power	ML-6442	6002-	1 Thru 16	250	22	6.3	0.9	—
			*7002-	17 Thru 20	250	25			
	Med. Power	ML-7289/3CX100A5	6003-	1 Thru 16	900	90	6.0	1.0	—
			*7003-	17 Thru 22	900	90			

These columns list nominal operating conditions only. Contact factory for specific application details.

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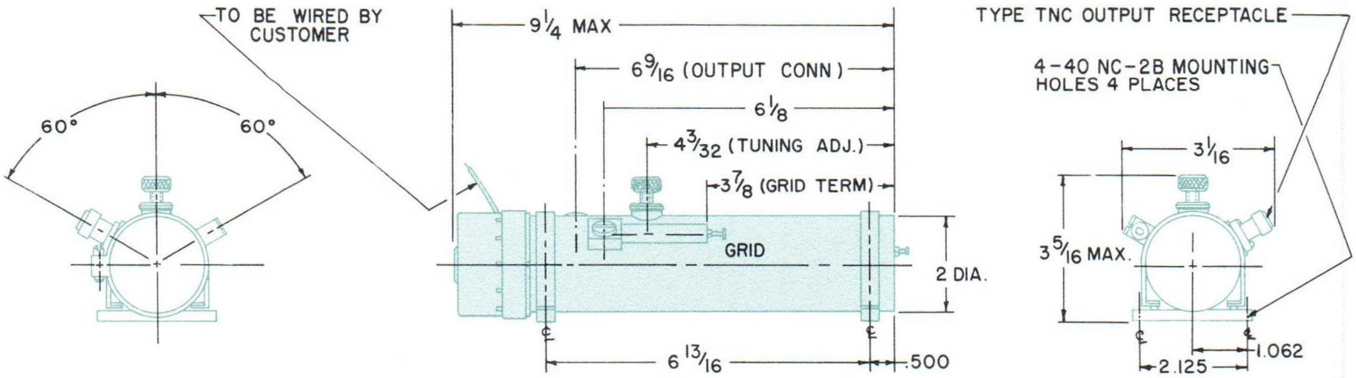
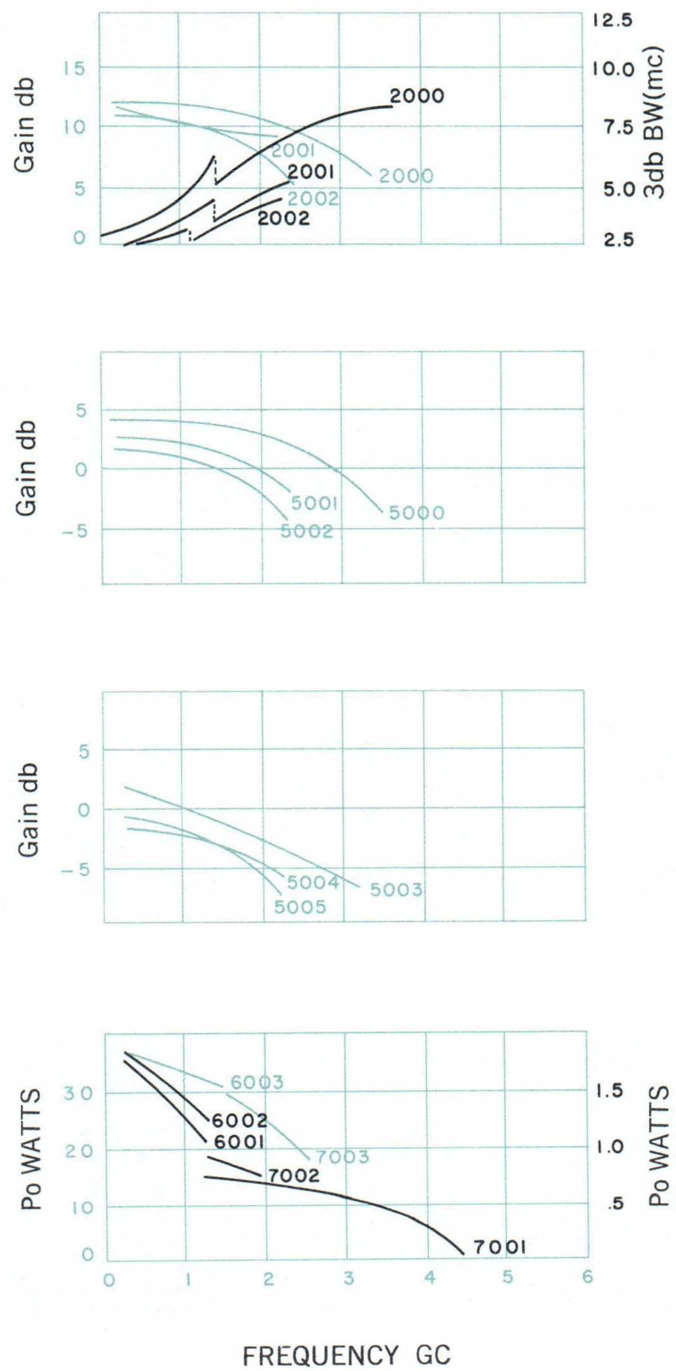
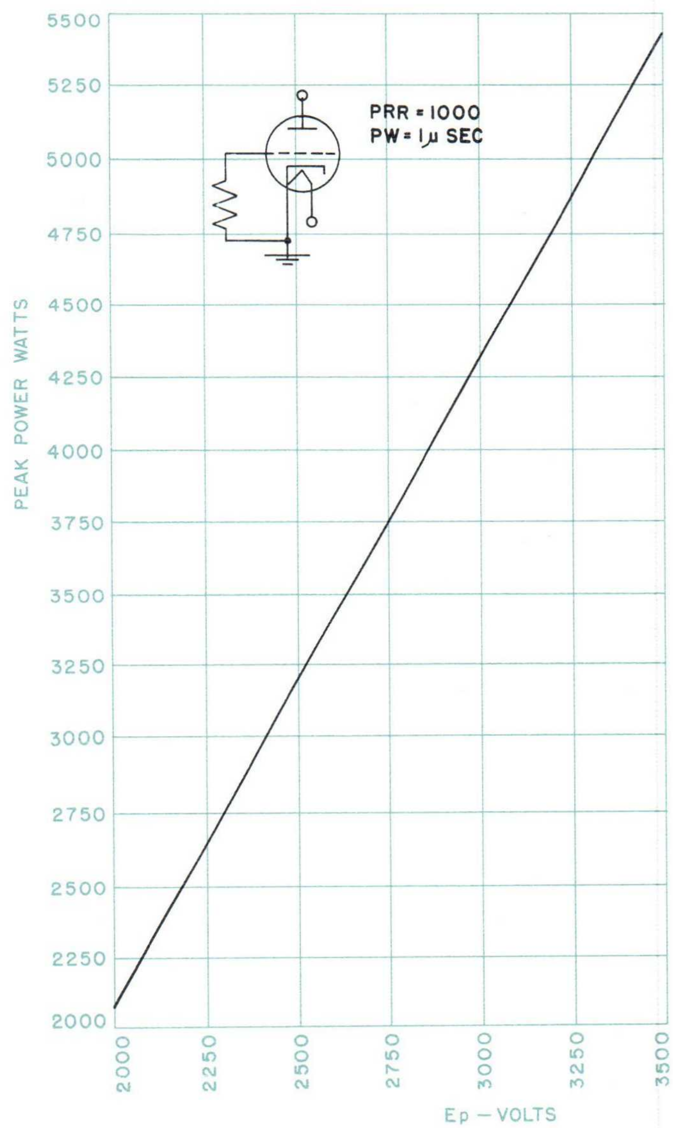
*Re-entrant oscillator

Model D-600 — Typical Oscillator Cavity







Conditions: ML-7698

Re-entrant oscillator

Frequency: 1600 mc

Efficiency: 30% to 40%

Resdel Engineering Corporation, Pasadena, California

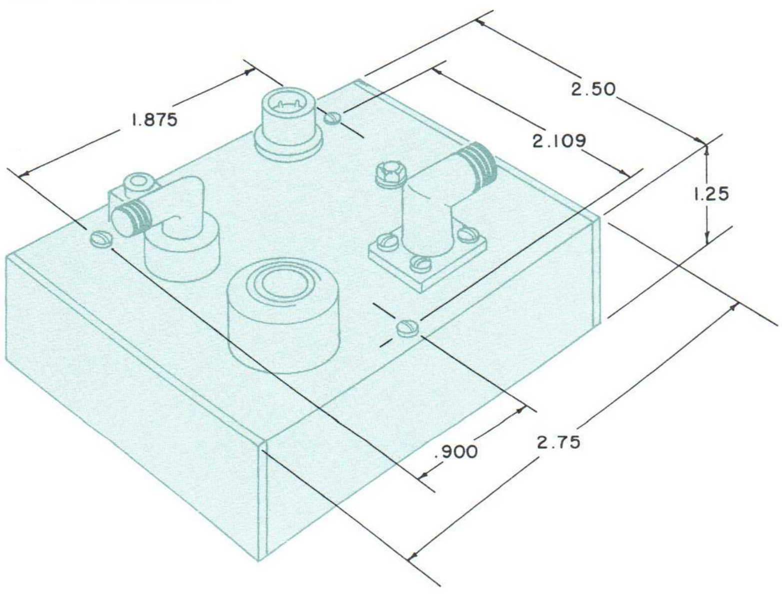
The Resdel Engineering Corporation makes available a series of miniature cavity devices for the frequency range of 400mc to 2325mc (or higher, upon consultation with Resdel). Each cavity is offered in 6 output frequency ranges. The ML-6442, ML-6771, and ML-7289/3CX100A5 UHF planar triodes may be used in Resdel cavities.

Model & Description	Gain in db at 250 mc	Gain in db at 1000 mc	High Power Output (watts)	Typical Band-width in mc.	Input VSWR (max)	Power Requirements Htr	Power Requirements Plate	Typ. Tube Types
A-20 High Gain Amplifier	15	15	1	6	1.8:1	6.3v at .5a	250v at .025a	ML-6771 or ML-6442
P-20 Power Amplifier	9	8	4	7	1.8:1	6.3v at .5a	250v at .035a	ML-6771 or ML-6442
P-30 Power Amplifier	10	11	25	Half Power Bandwidth 15	1.8:1	6.3v at 1a	525v at .090a	ML-7289/ 3CX100A5
X2-30 Frequency Doubler	—	—	3	8	—	—	—	ML-7289/ 3CX100A5
X3-30 Frequency Tripler	—	—	2	7	—	—	—	ML-7289/ 3CX100A5
P-31 Power Amplifier	10	11	50	15	1.8:1	6.3v at 1a	1000v at .090a	ML-7289/ 3CX100A5

4 WATT POWER AMPLIFIER

SIZE (8.6 IN.^{3}) WT. (9 OZ.)

POWER CONNECTORS FOR ALL SERIES ARE: VIKING VR4/2AB13 RF CONNECTORS = (TM) GRFF 2270 AND 2272



Typical Cavity of A-20 Series — Uses ML-6771 or ML-6442

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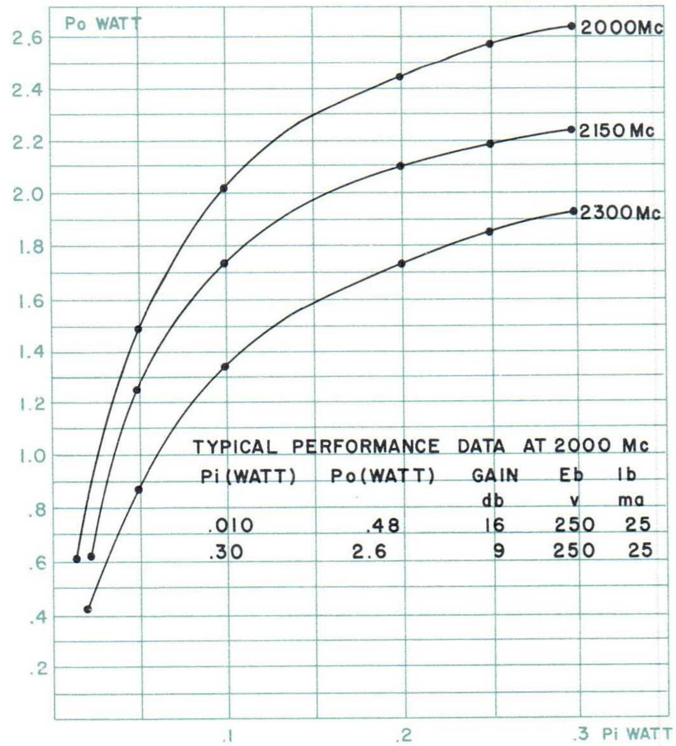
Ordering Information

Output Frequency Range (Mc)	Code Letter
400-550	C
650-800	D
800-970	E
950-1100	F
1350-1500	G
2075-2325	H

Example:

Model P-30E designates a 20 watt Power Amplifier for the 800-970 mc range.

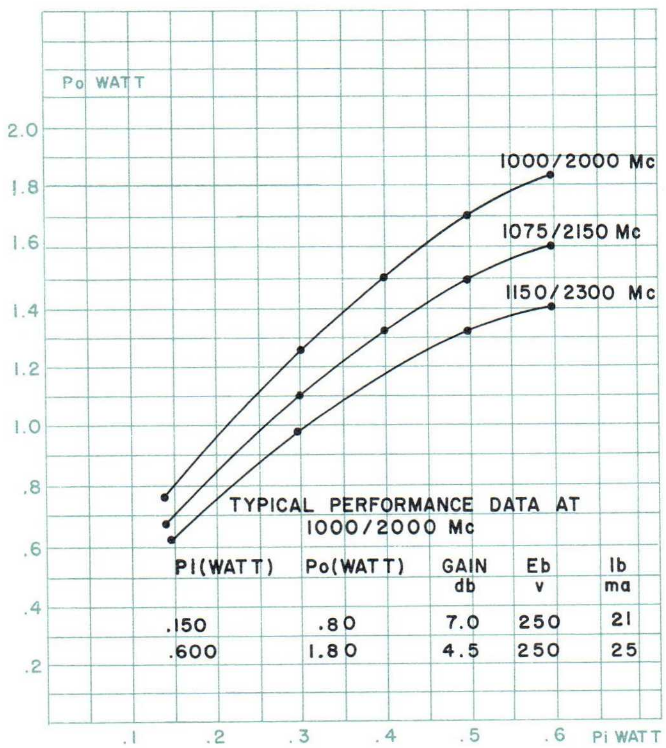
Note: In the case of doublers or triplers the frequency code refers to the output frequency.



Typical Output Power Curve

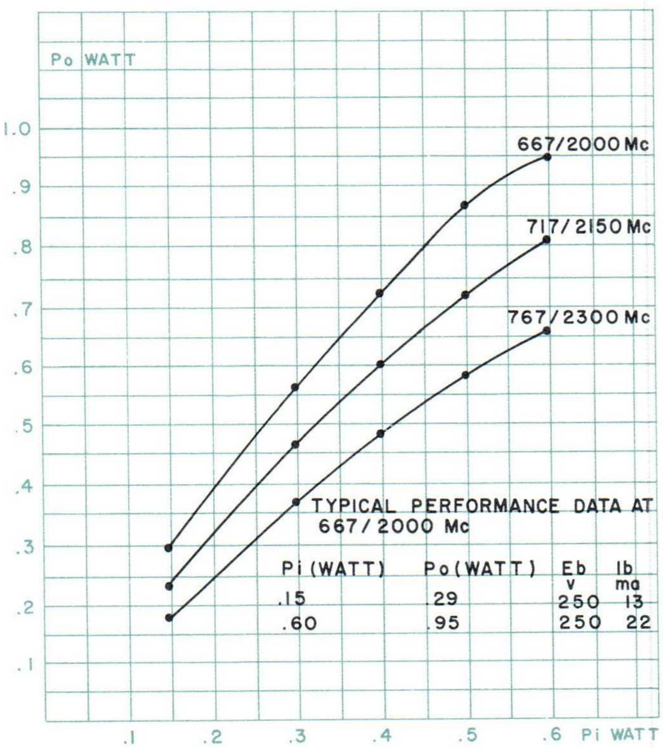
Cavity: P-20H with ML-6771

Amplifier Operation: Plate Voltage 250 v
Plate Current 25 ma



Typical Output Power Curve

Cavity: Frequency Doubler X2-20H with ML-6771



Typical Output Power Curve

Cavity: Frequency Tripler X3-20H with ML-6771

Gombos Microwave Inc., Clifton, New Jersey

Gombos Microwave Inc. makes available a line of cavities which includes oscillators for CW and pulsed service. These units are factory adjusted to cover 10% portions of the C, S, SL and L bands.

Machlett ML-6442 and ML-6771 planar triodes may be employed in C, S, SL and L band cavities as listed below. Modulation capabilities of these cavities include: Pulse, Square Wave, Sine Wave, Grid Switch and Varactor FM .2%.

CW

MODEL 101 SERIES

BAND	C	S	SL	L
Tuning	10%	10%	10%	10%
Minimum Output	10mw	15mw	20mw	30mw

MODEL 102 SERIES

BAND	C	S	SL	L
Tuning	—	10%	10%	10%
Minimum Output	—	30mw	60mw	100mw

MODEL 151 SERIES

BAND	C	S	SL	L
Tuning	1%	1%	1%	1%
Minimum Output	20mw	30mw	100mw	250mw

MODEL 153 SERIES

BAND	C	S	SL	L
Tuning	—	1%	1%	1%
Minimum Output	—	100mw	250mw	1w

Pulsed

MODEL 301 SERIES

BAND	C	S	SL	L
Tuning	10%	10%	10%	10%
Minimum Output	1kw	2kw	2½kw	3kw

MODEL 301C
Typical Operating Conditions

Peak Voltage: 2.4KV
Peak Current: 2.5 Amps.
Pulse Width: .2 to 1μs
P.R.F.: 1-2000 pps
Duty Cycle (Max.): .0015
Heater Voltage: 6.5V
Vibration: 20 G's (20-2000 cps)
Shock: 100 G's for 6 Milliseconds all planes
Temperature: 0°C-100°C
Connector: TNC
Heater Current: .65 Amps.

Performance Data

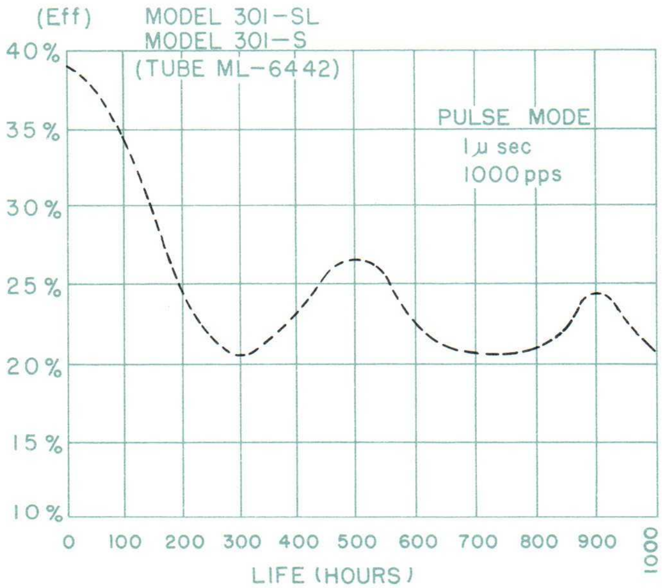


Figure 1: Efficiency of ML-6442 in Gombos Model 301 cavity over 1000 hour period at 3100 mc is shown. The percent figures reflect a change of power output from 2200 w to 2000 w over this period and indicate only a very slight change in tube plate impedance.

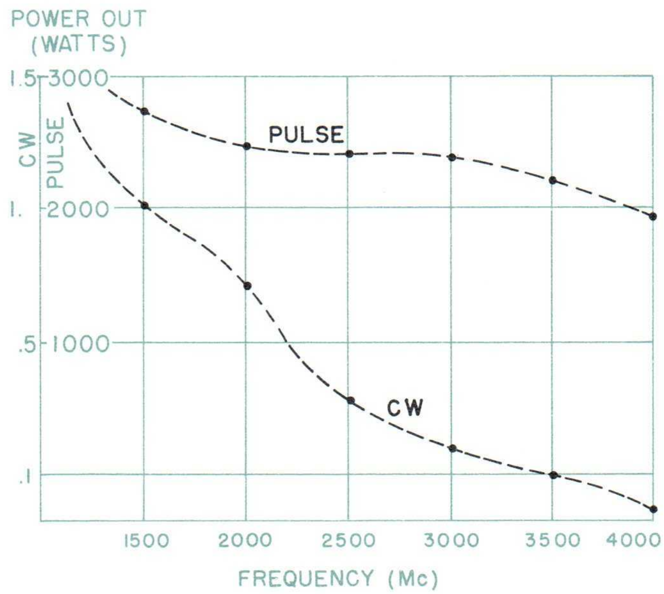


Figure 2: Power output vs Frequency:

		Pulsed	CW
Conditions:	Plate Voltage	3 kv	150 v
	Plate Current	2.5 a	25 ma

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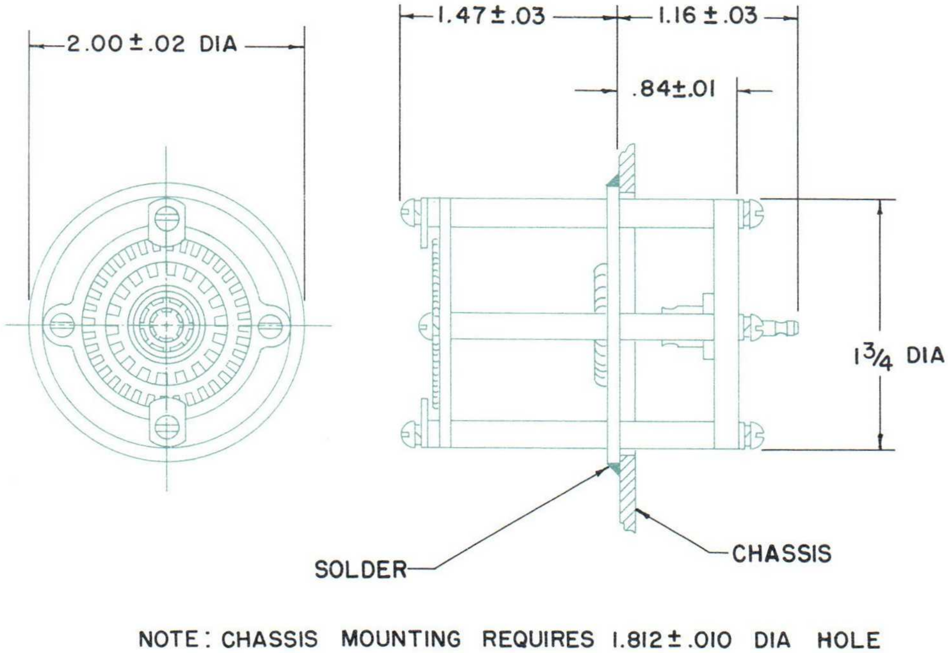
Jettron Products, Hanover, New Jersey

Jettron tube sockets are available for all Machlett UHF planar triodes.

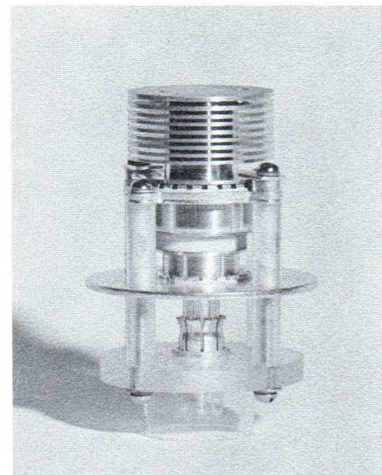
Tube Socket No. 76-020.

For ML-2C39A, ML-2C39WA, ML-2C41, ML-322, ML-7209, ML-7210, ML-7211, ML-7289/3CX100A5, ML-7698, ML-7815/3CPN10A5



CONTACTS: Beryllium copper, heat treated silver plated. Spring finger for all tube elements.

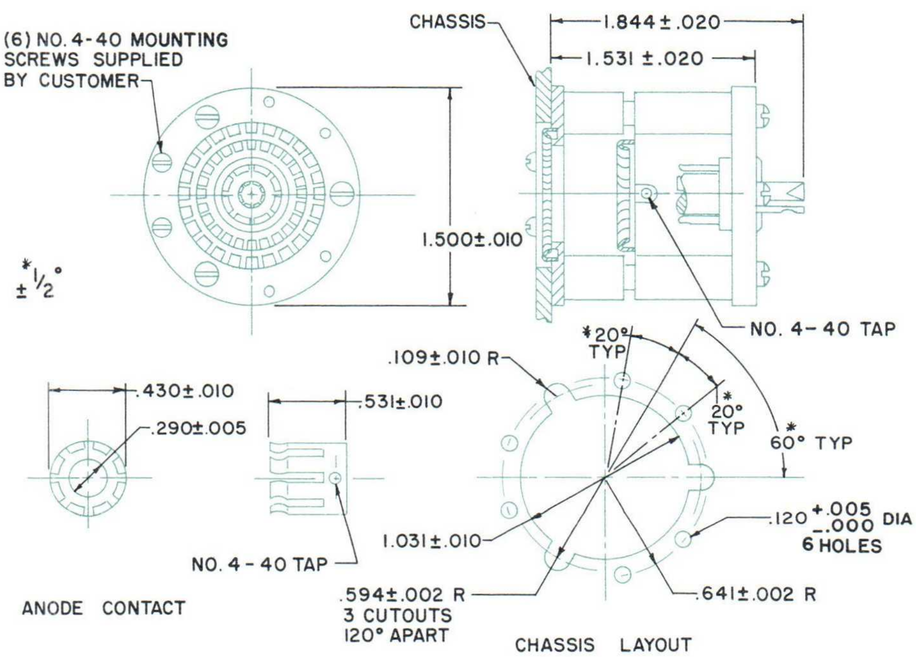
INSULATORS: Rexolite (low loss, low dielectric constant at VHF & UHF.) Anode & Heater contact areas minimized for low capacitance.



Note: Tube socket No. 76-051 similar to 76-020, used with ML-518. Tube socket No. 76-052 similar to 76-020, used with ML-7855. Other variations of 76- series are available.

Tube Socket No. 82-010, No. 82-014.

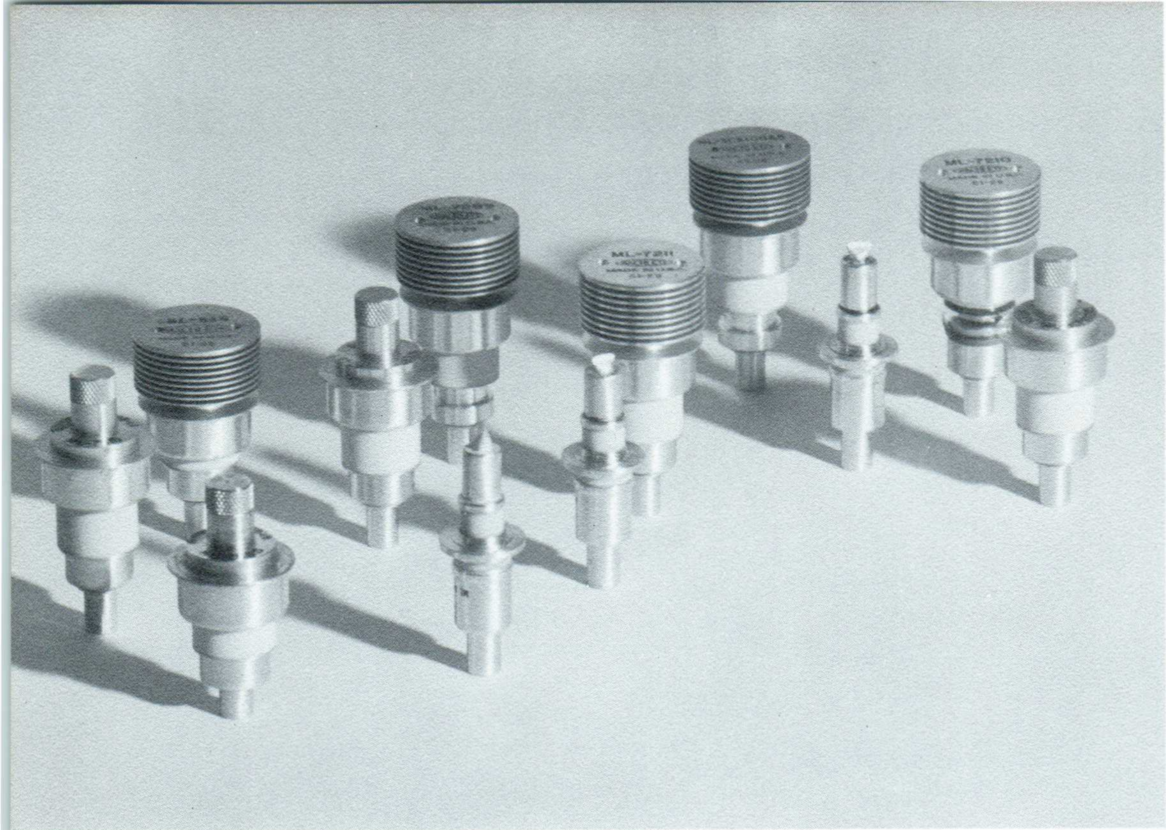
For ML-6442, ML-6771



No. 82-010 Rexolite Insulators

No. 82-014 KEL-F Insulators

General specifications similar to 76-000 series above. Other variations of 82- series available.



CONTACT SURFACE INFORMATION

Electron tube operation in the microwave region produces physical and electrical requirements which demand that one adhere strictly to them; this is particularly true above 500Mc. Of the greatest importance in this connection is the need for a precise and accurate fit of the tube in the cavity. It is essential that the contact areas be defined accurately and that the position in the socket be determined by a surface against which the contact surfaces are held with close tolerances. The tube manufacturers have provided for this need by incorporating such "tight-tolerance" contact surfaces referenced against a surface which also serves as a tube stop when the tube is inserted in the cavity. It is the purpose of this note to point out the existence and location of these surfaces on Machlett tubes and to stress the importance of observing this data. If one considers, for example, that a dimensional shift of a non-designated surface* (yet one entirely within specifications) can cause a change of 100Mc or more in cavity tuning, one can realize how necessary it is to observe and follow contact surface requirements as indicated on the accompanying drawings.

When the proper tube stop (reference surface) and contact surfaces are employed, the risk of faulty tube to cavity contact and positioning is avoided. Faulty positioning and resulting faulty contact can produce one or more of the following problems:

Improper tuning
Reduced power output
Cavity damage
Tube breakage

The use of a surface other than the designated reference surface as a stop, can easily lead to any of the above failures. Since it is economically impractical to hold all dimensions to sufficiently tight tolerances to permit their use as a tube stop and/or reference surface, only one, at the upper edge of the anode contact, is provided on the tubes listed under Figure 1, page 35.

All contact surfaces must be located from this tube stop or reference surface. The contact areas shown in these drawings are in agreement with those of other tube manufacturers making the same tube types.

To provide a verified example for spring-finger-contact design, we list parts commercially available at this time†. It should be emphasized, however, that these parts are suggested designs only and that other suitable means of providing tube contact may be equally satisfactory.

Since the **ML-6442** and the **ML-6771** usually utilize double-ended cavities (one section for grid-plate, the other for cathode-grip), these tubes provide two surfaces as a primary tube stop, one on top of the grid flange, the other on the bottom. The location of the contact surfaces, however, are only referenced against one surface. Depending on cavity design a secondary tube stop may or may not be required. If such a stop is required on the cathode end, we suggest the use of a third surface located on the bottom edge of the cathode contact (see Figure 2). Use of this surface as a stop is recommended in order to keep the center heater contact (heater contact No. 2) from being so used, and thereby protecting it from insertion damage. When using this particular stop at the cathode contact it is advisable to use an insulating material as a stop. It is realized that the use of this secondary tube stop will have effects on tuning of the cathode-grid section of the cavity, when interchanging tubes. These effects, however, are only minor because the Q of the grid-cathode section is generally low, i.e., the tuning curve in this section is essentially flat. It is well to note that the use of the rounded upper edge or lip of the cathode provides an uncertain stop, and one which can be overridden when a tube is vigorously inserted.

When a secondary tube stop is used in conjunction with the anode, care must be taken to see that the stop clears the seal-off tubulation. Damage to the tubulation can cause a leak.

†Instrument Specialties Corporation. See also page 24.

*A surface not designated as a reference or stop by the tube manufacturer.

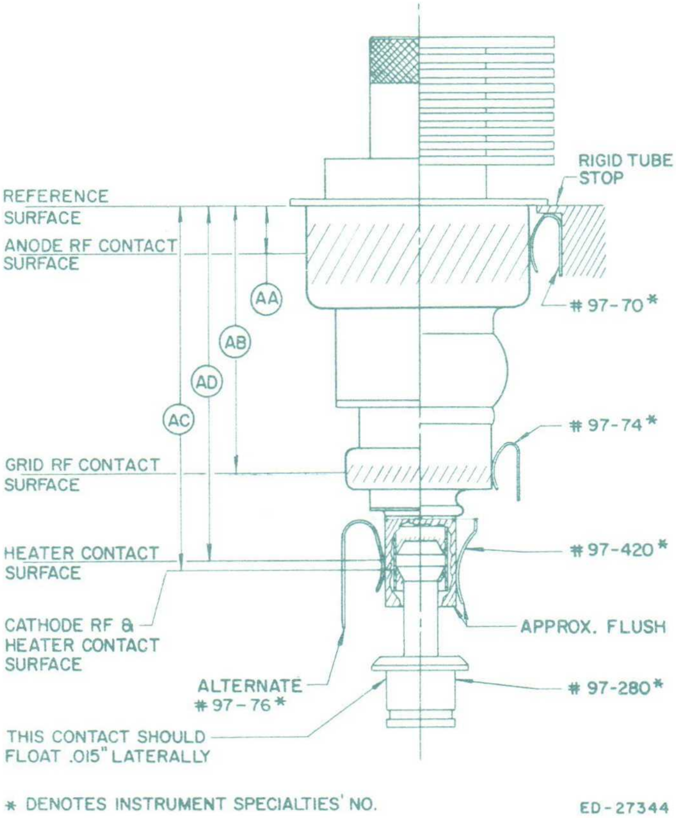


Figure 1 — Contact surface drawing — ML-2C39A, ML-2C39WA, ML-2C41, ML-322, ML-518, ML-7209, ML-7210, ML-7211, ML-7289/3CX100A5, ML-7698, ML-7815/3CPN10A5, ML-7855.

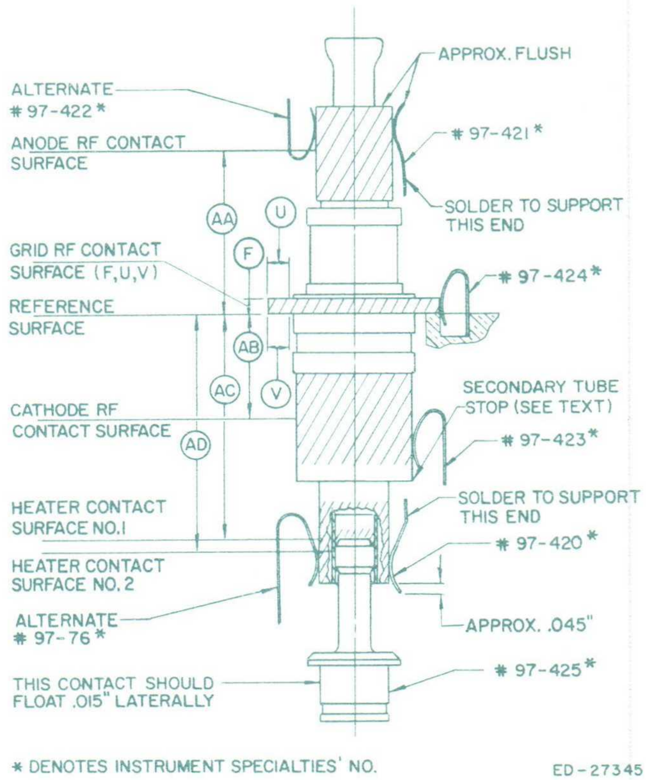


Figure 2 — Contact surface drawing — ML-6442 and ML-6771.

UHF Triodes

TUBE TYPE	Design Group	UHF Application	Maximum Frequency of Operation for Full Ratings
ML-2C39A Forced-Air-Cooled	#3	Oscillator, Amplifier, Frequency Multiplier	2500 mc/sec.
ML-2C39WA Forced-Air-Cooled	#2	Oscillator, Amplifier, Frequency Multiplier	2500 mc/sec.
ML-2C41 Forced-Air-Cooled	#3	Plate-pulsed Oscillator, Amplifier	3000 mc/sec.
ML-518* Forced-Air-Cooled	#1	Oscillator, Amplifier, Frequency Multiplier (Frequency stable anode; 600V anode for rated power)	2500 mc/sec.
ML-6442* Conduction/Convection Cooled	#1	Plate-pulsed Oscillator, Amplifier, Frequency Multiplier	5000 mc/sec.
ML-6771* Conduction/Convection Cooled	#1	Oscillator, Amplifier, Frequency Multiplier	4000 mc/sec.
ML-7209 Forced-Air-Cooled	#2	Plate-pulsed Oscillator, Amplifier, Frequency Multiplier (High shock ratings)	3000 mc/sec.
ML-7210* Forced-Air-Cooled	#2	Plate-pulsed Oscillator, Amplifier, Frequency Multiplier Oscillator, Amplifier, Frequency Multiplier (12 second warm-up cathode)	3000 mc/sec. 2500 mc/sec.
ML-7211* Forced-Air-Cooled	#1	Oscillator, Amplifier, Frequency Multiplier (High cathode current capability)	2500 mc/sec.
ML-7289/3CX100A5* Forced-Air-Cooled	#1	Oscillator, Amplifier, Frequency Multiplier	2500 mc/sec.
ML-7698* Conduction/Convection Cooled	#1	Plate- or Grid-pulsed Oscillator, Amplifier, Frequency Multiplier (High cathode current capability)	3000 mc/sec.
ML-7815/3CPN10A5* Conduction/Convection Cooled	#1	Plate- or Grid-pulsed Oscillator, Amplifier, Frequency Multiplier	3000 mc/sec.
ML-7855* Forced-Air-Cooled	#1	Oscillator, Amplifier, Frequency Multiplier (Frequency stable anode)	2500 mc/sec.

UHF Planar Diode

TUBE TYPE	Design Group	UHF Application	Maximum Frequency of Operation for Full Ratings
ML-322* Forced-Air-Cooled	#2	Modulation Clipper	1500 mc/sec.

***New Equipment design interest.**

Design Group **#1** Ceramic envelope; coaxial terminals; ruggedized planar electrodes; tightly held concentricity tolerances; exacting production specifications. Low interelectrode capacitance; low lead inductance; close production and testing control of cathode activity.

Design Group **#2** Similar to Group #1 except for use of glass envelope.

Design Group **#3** Glass envelope; coaxial terminals; planar electrodes. Low interelectrode capacitance; low lead inductance.

	FILAMENT Voltage Volts	FILAMENT Current Amps.	Mμ	Gm	Duty	MAXIMUM RATINGS PLATE Volts	MAXIMUM RATINGS CATHODE Current Amps.	MAXIMUM RATINGS GRID Voltage Volts	MAXIMUM RATINGS GRID Current Amps.	Average Plate Dissipation Watts	TUBE TYPE
ML-2C39A	6.3	1.0	100	24000	CW	1000	0.125	−150	0.050	100	**ML-2C39A** Forced-Air-Cooled
ML-2C39WA	6.0	1.0	100	25000	CW	1000	0.125	−150	0.050	100	**ML-2C39WA** Forced-Air-Cooled
ML-2C41	6.3	1.03	100	25000	0.0025	3500‡	6.5§	−150	2.5§	35	**ML-2C41** Forced-Air-Cooled
ML-518*	6.0	1.0	100	25000	CW	600	0.125	−150	0.030	100	**ML-518*** Forced-Air-Cooled
ML-6442*	6.3	0.90	50	16500	0.001	3000‡	3.75§	−100	1.25§	8	**ML-6442*** Conduction/Convection Cooled
ML-6771*	6.3	0.57	90	23000	CW	300	0.033	−25	0.008	6.25	**ML-6771*** Conduction/Convection Cooled
ML-7209	6.0	1.0	100	25000	.0033	3500‡	4.5§	−150	1.5§	35	**ML-7209** Forced-Air-Cooled
ML-7210*	6.3	0.85	75	17000	CW 0.0025	1000 3500‡	.095 4.0§	−150 −150	0.030 1.2§	100 25	**ML-7210*** Forced-Air-Cooled
ML-7211*	6.3	1.3	80	30000	CW	1000	0.190	−150	0.045	100	**ML-7211*** Forced-Air-Cooled
ML-7289/ 3CX100A5*	6.0	1.0	100	25000	CW	1000	0.125	−150	0.050	100	**ML-7289/3CX100A5*** Forced-Air-Cooled
ML-7698*	6.3	1.3	80	30000	0.0025	3500‡ 2000 (grid pulsed)	7.5§	−150	2.5§	10†	**ML-7698*** Conduction/Convection Cooled
ML-7815/ 3CPN10A5*	6.0	1.0	100	25000	0.0025	3500‡ 2000 (grid pulsed)	4.8§	−150	1.8§	10†	**ML-7815/3CPN10A5*** Conduction/Convection Cooled
ML-7855*	6.0	1.0	80	25000	CW	1000	0.125	−150	0.030	100	**ML-7855*** Forced-Air-Cooled
				Peak Inverse Anode Voltage Volts				Peak Anode Current Amps.			
ML-322*	6.3	0.95		800				0.60			**ML-322*** Forced-Air-Cooled

†Greater anode dissipation may be achieved with Conduction — and/or Forced-Air-Cooling.
‡Plate pulsed
§Peak

ML-2C39A

General purpose application.

DESCRIPTION

The **ML-2C39A** is a high-mu triode of the planar-electrode type designed specifically for use as an oscillator, frequency multiplier, or power amplifier in radio transmitting service from low frequency to above 2500 Mc. Features include low interelectrode capacitances, high transconductance, and high plate dissipation. Lead inductances and r.f. losses are minimized by a compact, rugged construction with ring type seals, making the tube ideally suited to cavity type circuits as well as for parallel line operation. The cathode is an indirectly-heated, oxide-coated disc. The anode is forced-air cooled and is capable of dissipating 100 watts.

The **ML-2C39A** embodies the highest standards of this tube type. All parts are thoroughly processed by special Machlett techniques to assure efficient operation and long life.

GENERAL CHARACTERISTICS

Electrical		
Heater Voltage	6.3	Volts†
Heater Current at 6.3 Volts	1.0	Amps
Heater Heating Time, minimum (Before Applying Plate Voltage)	60	Seconds
Amplification Factor	100	
Transconductance (I_b = 70 mA, E_b = 600 v)	24,000	umhos
Interelectrode Capacitances		
Grid-Plate	2.0	uuf
Grid-Cathode	6.60	uuf
Plate-Cathode, maximum	0.035	uuf
Mechanical		
Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Incoming Air Temperature	45	°C
Required Air Flow on Anode	12.5	cfm*
Maximum Anode Temperature	175	°C
Net Weight	2	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

R-F Power Amplifier and Oscillator

Key-down conditions per tube without amplitude modulation‡

Maximum Ratings, Absolute Values

D-C Plate Voltage	1000	volts
D-C Grid Voltage	-150	volts
D-C Cathode Current	125	mA
D-C Grid Current§	50	mA
Peak Positive RF Grid Voltage	30	volts
Peak Negative RF Grid Voltage	-400	volts
Plate Dissipation† (Forced-air Cooling)	100	watts
Grid Dissipation	2	watts

Typical Operation

Power Amplifier, Grid Separation Circuit — 500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage	-40	volts
D-C Cathode Current	115	mA
D-C Plate Current	90	mA
D-C Grid Current, Approximate	30	mA
Plate Input	64	watts
Driving Power, Approximate	6	watts
Useful Power Output	40	watts

RF Oscillator — 2500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage (from grid-bias resistor) (approx.)	-22	volts
D-C Plate Current	90	mA
D-C Grid Current	27	mA
Useful Power Output	17	watts

Note: These conditions are for a grid-blocking oscillator and conform to the minimum power output requirements as specified in such a test by the MIL-E-1 specification for 2C39A tubes.

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*	600	volts
D-C Grid Voltage	-150	volts
D-C Cathode Current	100	mA
D-C Grid Current§	50	mA
Peak Positive RF Grid Voltage	30	volts
Peak Negative RF Grid Voltage	-400	volts
Plate Dissipation† (Forced-air Cooling)	70	watts
Grid Dissipation	2	watts

Characteristic Range Values for Equipment Design

	Min.	Max.	
Filament Current at 6.3 volts (Note 1)	0.95	1.1	A
Plate Current (Note 2)	60	95	mAdc
Cut-off bias (Note 3)	——	-15	volts
Transconductance	20000	30000	umhos
Grid-Plate Capacitance	1.86	2.16	uuf
Grid-Cathode Capacitance (Note 4)	5.60	7.60	uuf
Plate tuning range (Note 5)	1960	2030	Mc

Note 1 — For reduced filament voltage see filament volt-ampere characteristics on page 3.

Note 2 — Measured at a plate voltage of 600 volts and a cathode-bias resistor of 30 ohms.

Note 3 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

Note 4 — Capacitance measurements are with the tube cold. When the filament is heated to proper operating temperature, the grid to cathode capacitance will increase by about 1 uuf, due to thermal expansion of the cathode.

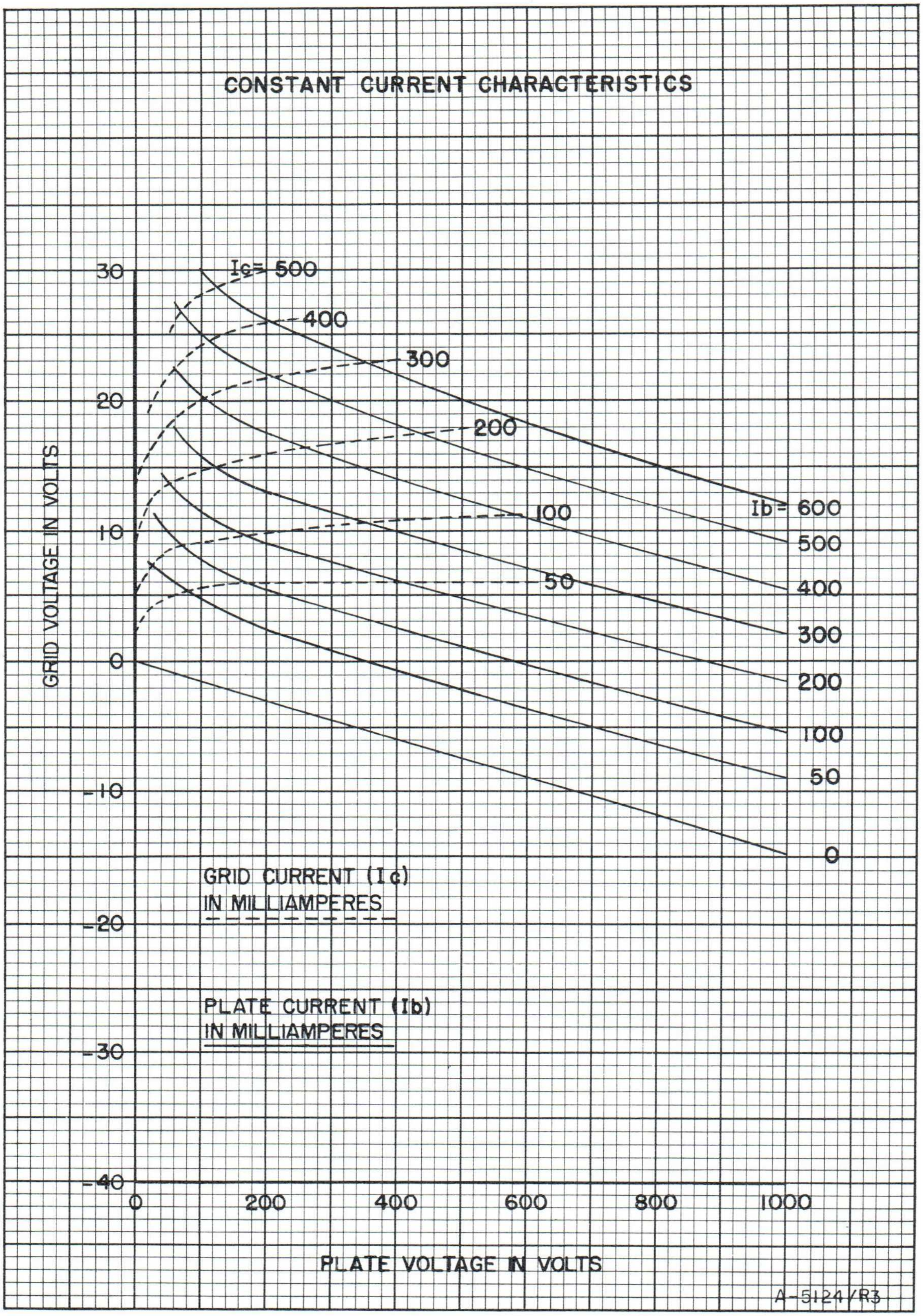
Note 5 — With a plate-grid coaxial cavity of fixed dimensions, all tubes will resonate within the specified frequency range.

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

§See Application Notes on Determination of Proper Grid Drive.

†Up to 100 watts plate dissipation allowable with forced air sufficient to limit seal temperatures to 175°C. Recommended air flow is 12.5 cubic feet per minute with cowling.

*For modulation factors less than 1.0, a higher d-c plate voltage may be used if the sum of the peak audio voltage and the d-c plate voltage does not exceed 1200 volts.


CONSTANT CURRENT CHARACTERISTICS
Ic= 500
400
300
200
100
50
Ib= 600
500
400
300
200
100
50
0
30
20
10
0
-10
-20
-30
-40
GRID VOLTAGE IN VOLTS
GRID CURRENT (Ic)
IN MILLIAMPERES
PLATE CURRENT (Ib)
IN MILLIAMPERES
0
200
400
600
800
1000
PLATE VOLTAGE IN VOLTS
A-5124/R3

ML-2C39WA

Ruggedized structure. General purpose application.

DESCRIPTION

The **ML-2C39WA** is a ruggedized high-mu triode of planar-electrode type designed specifically for use as an oscillator, frequency multiplier or power amplifier in radio transmitting service at frequencies up to 2500 Mc.

The **ML-2C39WA** is interchangeable with the **ML-2C39A.** This tube retains the desirable high mu, high transconductance characteristics of the **ML-2C39A** together with its low interelectrode capacitances and compact, rugged ring-seal construction.

The **ML-2C39WA** is the result of an intensive development program with respect to the proper selection and processing of tube materials, particularly with regard to the cathode, to provide improved life, reliability and stability of operation. This tube is manufactured and tested to close tolerances to insure consistent and uniform tube performance.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.0	Volts†
Heater Current (AC or DC) at 6.0 Volts	1.0	Amp
Heater Heating Time, minimum	60	secs
Amplification Factor	100	
Transconductance		
(I_b = 70 mA, E_b = 600 v)	25,000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.0	μμf
Grid-Cathode	6.60	μμf
Plate-Cathode, maximum	0.035	μμf
Frequency for Maximum Ratings	2500	Mc

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Anode Temperature	200	°C
Net Weight	2.0	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

R-F Power Amplifier and Oscillator

Key-down conditions per tube without amplitude modulation‡

Maximum Ratings, Absolute Values

D-C Plate Voltage	1000	volts
D-C Grid Voltage	−150	volts
D-C Cathode Current	125	mA
D-C Grid Current§	50	mA
Peak Positive R-F Grid-Cathode Voltage	30	volts
Peak Negative R-F Grid-Cathode Voltage	−400	volts
Plate Dissipation† (Forced-air Cooling)	100	watts
Grid Dissipation	2	watts

Typical Operation

Power Amplifier, Grid Separation Circuit — 500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage	−40	volts
D-C Plate Current	90	mA
D-C Grid Current, Approximate	30	mA
Driving Power, Approximate	6	watts
Useful Power Output	40	watts

R-F Oscillator — 2500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage, Approximate	−22	volts
D-C Plate Current	90	mA
D-C Grid Current	10	mA
Useful Power Output	17	watts

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*	600	volts
D-C Grid Voltage	−150	volts
D-C Cathode Current	100	mA
D-C Grid Current§	50	mA
Peak Positive R-F Grid Voltage	30	volts
Peak Negative R-F Grid Voltage	−400	volts
Plate Dissipation† (Forced-air Cooling)	70	watts
Grid Dissipation	2	watts

Characteristic Range Values for Equipment Design

	Min.	Max.	
Filament Current at 6.0 volts	0.90	1.05	amps
Cut-off bias (Note 1)	—	−15	volts
Grid-Plate Capacitance (Note 2)	1.86	2.16	$\mu\mu f$
Grid-Cathode Capacitance (Note 2)	5.60	7.60	$\mu\mu f$

Note 1 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

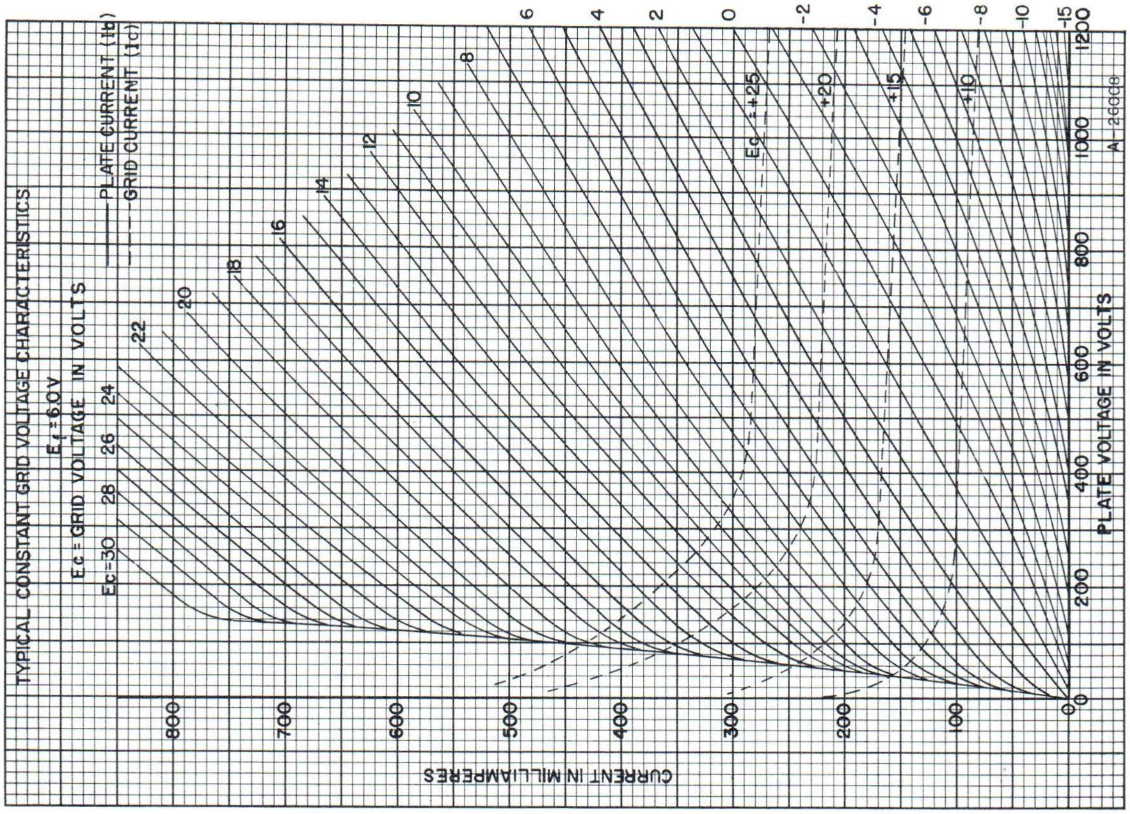
Note 2 — Capacitance measurements are with the tube cold.

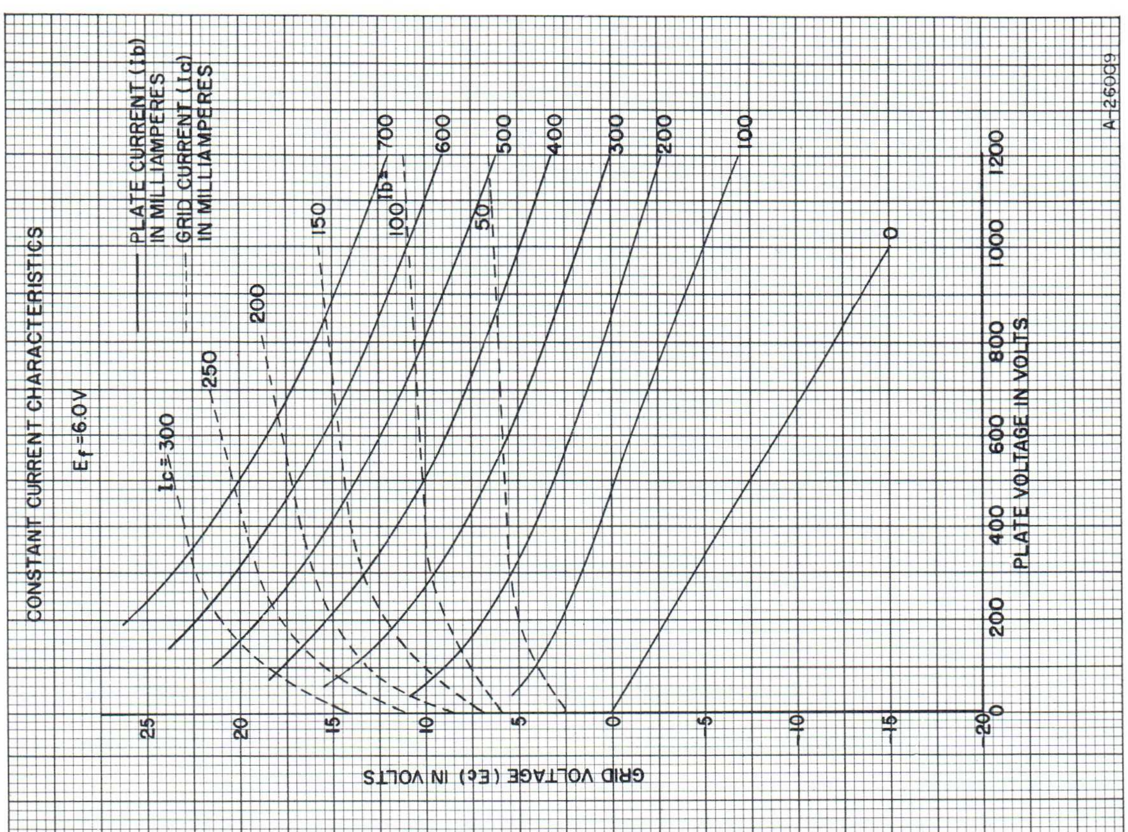
‡Modulation essentially negative may be used if the positive peak of the envelope does not exceed 115 per cent of the carrier conditions.

§See "Application Notes" on "Determination of Proper Grid Drive".

†Refer to "Cooling" under "Application Notes".

*For modulation factors less than 1.0, a higher d-c plate voltage may be used if the sum of the peak audio voltage and the d-c plate voltage does not exceed 1200 volts.


TYPICAL CONSTANT GRID VOLTAGE CHARACTERISTICS
Ef = 6.0V
Ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (Ib)
GRID CURRENT (Ic)
CURRENT IN MILLIAMPERES
PLATE VOLTAGE IN VOLTS
A-26008


CONSTANT CURRENT CHARACTERISTICS
Ef = 6.0V
PLATE CURRENT (Ib) IN MILLIAMPERES
GRID CURRENT (Ic) IN MILLIAMPERES
GRID VOLTAGE (Ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-26009

ML-2C41

Plate-pulsed oscillator service.

DESCRIPTION

The **ML-2C41** is a high-mu triode of the planar-electrode type designed for use as a plate-pulsed oscillator, or power amplifier in radio transmitting service from low frequency to 3000 Mc. Features include low interelectrode capacitances, high transconductance and great mechanical strength. Lead inductances and r.f. losses are minimized by a compact, rugged construction with ring-type seals, making the tube ideally suited to cavity type circuits as well as for parallel line operation. The cathode is an indirectly-heated, oxide-coated disc. The anode is forced-air cooled.

The **ML-2C41** embodies the highest standards of this tube type. All parts are thoroughly processed by special Machlett techniques to assure efficient operation and long life.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.3	volts†
Heater Current at 6.3 volts	1.03	amps
Heater Heating Time, minimum	60	secs
Amplification Factor	100	
Transconductance (I_b = 70 mA, E_b = 600 v)	25000	umhos
Interelectrode Capacitances		
Grid-Plate	2.01	uuf
Grid-Cathode	6.60	uuf
Plate-Cathode	0.035	uuf max.
Duty Cycle	0.0025	
Maximum Pulse Length	3	usecs

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Anode Temperature	175	°C
Net Weight	2¼	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Plate-Pulsed Oscillator and Amplifier—Class C

Maximum Ratings, Absolute Values

For a pulse length of *	3	usec
Duty Factor *	0.0025	
Peak Plate Pulse Supply Voltage	3500	volts
Peak Grid Bias Voltage	-150	volts
Peak Plate Current from Pulse Supply	4	amps
Average Plate Current	10	mA
Average Grid Current	6	mA
Average Plate Dissipation	35	watts
Average Grid Dissipation	2	watts
Frequency	3000	Mc

Typical Operation: 2500 Mc Oscillator

Pulse Length	3	usec
Duty Factor	0.0025	
Peak Plate Pulse Supply Voltage	3500	volts
Peak Grid Bias Voltage	-100	volts
Peak R-F Grid Voltage	340	volts
Peak R-F Plate Voltage	2500	volts
Peak Plate Current from Pulse Supply	3	amps
Average Plate Current	7.5	mA
Average Grid Current	4.5	mA
Driving Power During Pulse, Approximate	450	watts
Useful Power Output at Peak of Pulse, Approx.	2200	watts
Pulse Recurrence Rate	825	pps

*For applications above a duty factor of 0.0025 and a pulse width of 3 μsec, contact the Machlett Engineering Department for information.

Characteristic Range Values for Equipment Design

	Min.	Max.	
Filament Current at 6.3 volts (Note 1)	0.95	1.10	A
Plate Current (Note 2)	60	95	mAdc
Cut-off Bias (Note 3)	—	-15	Vdc
Transconductance	20,000	30,000	umhos
Grid-Plate Capacitance	1.86	2.16	uuf
Grid-Cathode Capacitance (Note 4)	5.60	7.60	uuf
Plate-Cathode Capacitance	—	.035	uuf
Plate Tuning Range (Note 5)	1960	2030	Mc

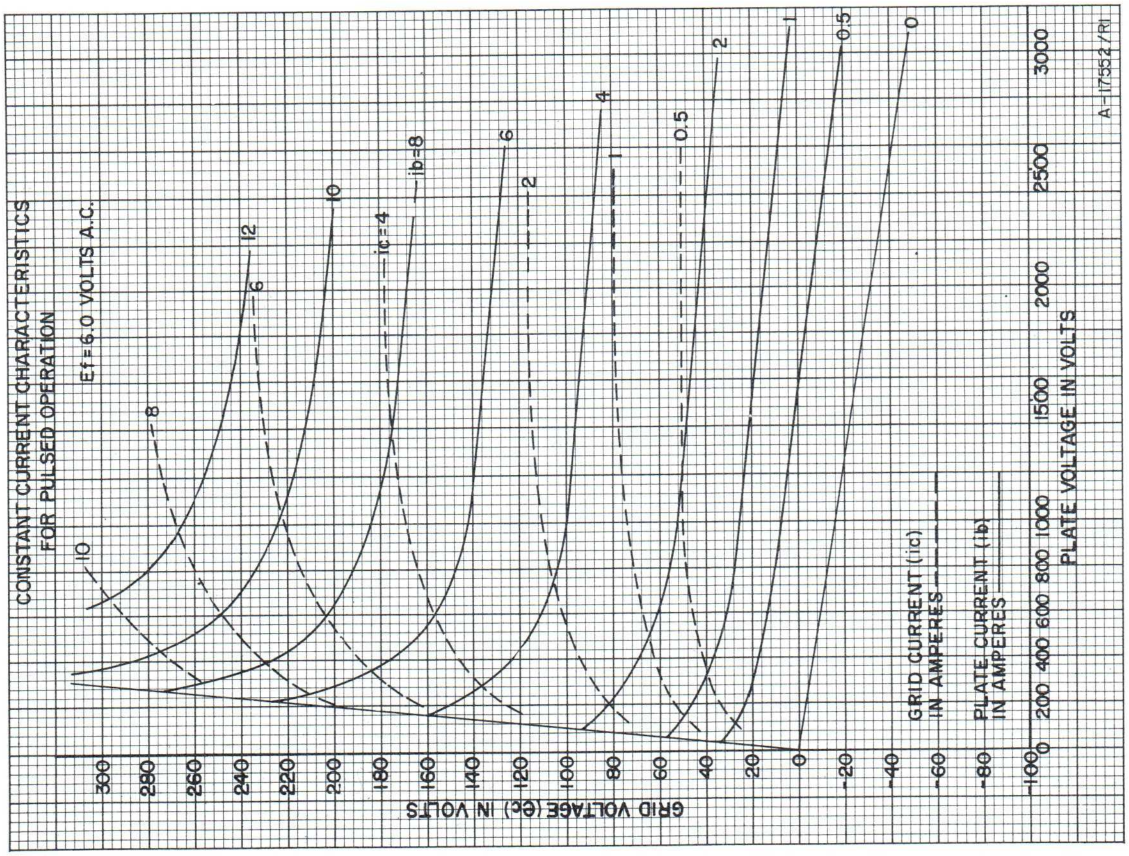
Note 1 — For reduced filament voltage see "Heater Voltage" section under "Application Notes".

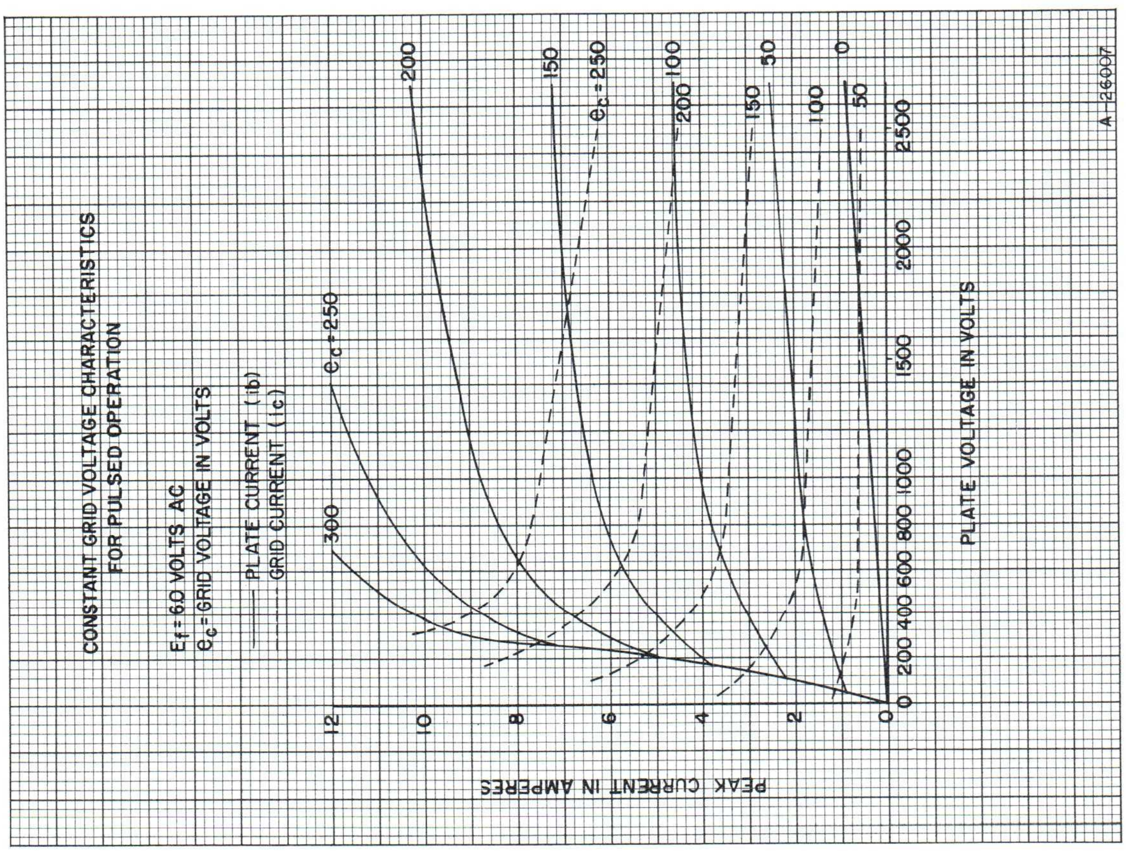
Note 2 — Measured at a plate voltage of 600 volts and a cathode-bias resistor of 30 ohms.

Note 3 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

Note 4 — Capacitance measurements are with the tube cold. When the filament is heated to proper operating temperature the grid-cathode capacitance will increase by about 1 uuf due to thermal expansion of the cathode.

Note 5 — With a plate-grid coaxial cavity of fixed dimensions, all tubes will resonate within the specified frequency range.


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS A.C.
GRID CURRENT (ic) IN AMPERES
PLATE CURRENT (ib) IN AMPERES
PLATE VOLTAGE IN VOLTS
GRID VOLTAGE (ec) IN VOLTS
A-17552/R1


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS AC
ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
PLATE VOLTAGE IN VOLTS
PEAK CURRENT IN AMPERES
A-26007

ML-322

Clipper diode.

DESCRIPTION

The ML-322 is an ultra-high-frequency diode of the planar-electrode type designed for use as a modulation clipper at frequencies up to 1500 Mc. Lead inductances and r-f losses are minimized by a compact, rugged construction with ring-type seals, making the tube ideally suited to cavity-type circuits. The electrode spacing is about 0.008″. The cathode is an indirectly-heated, oxide-coated disc. The anode is convection cooled and is capable of dissipating 15 watts.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.3	Volts †
Heater Current at 6.3 volts, approximate	.95	Amps
Heater Heating Time, minimum (Before Applying Plate Voltage)	60	Seconds
Interelectrode Capacitance	3.5	uuf

Mechanical

Mounting Position	Optional	
Maximum Seal Temperature	160	°C
Net Weight, approximate	0.25	lbs.

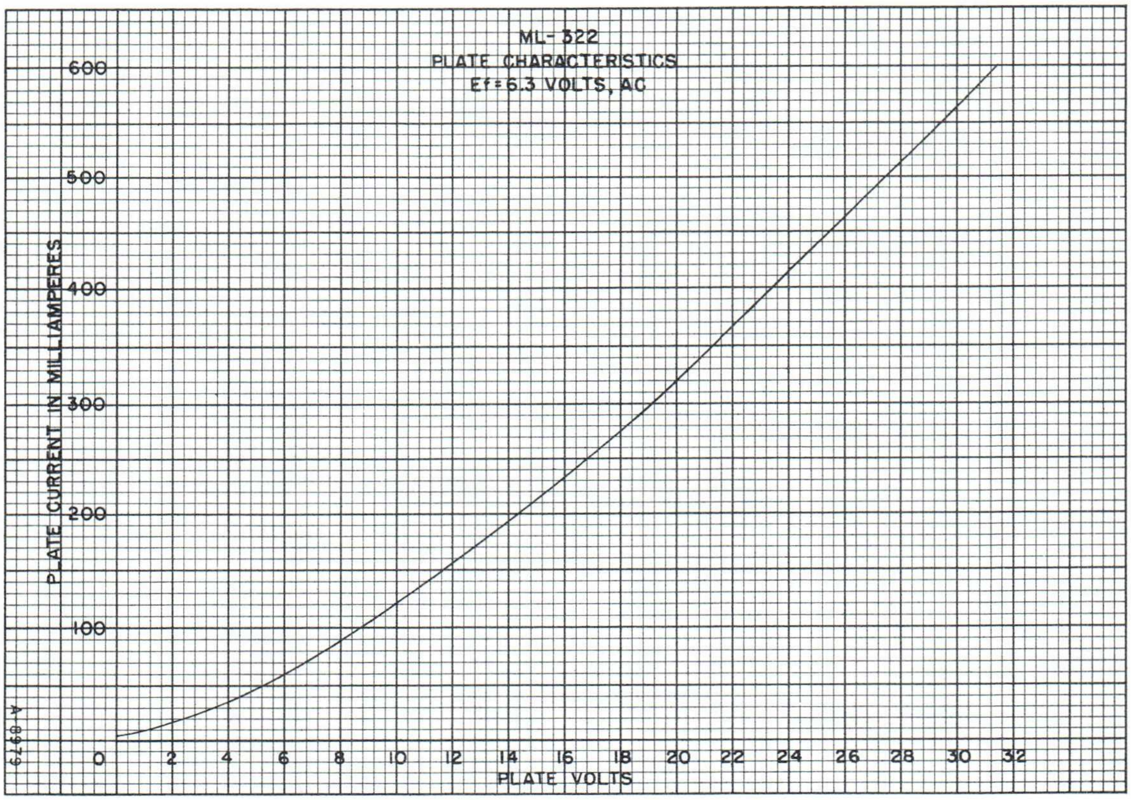
MAXIMUM RATINGS

Maximum Ratings, Absolute Values

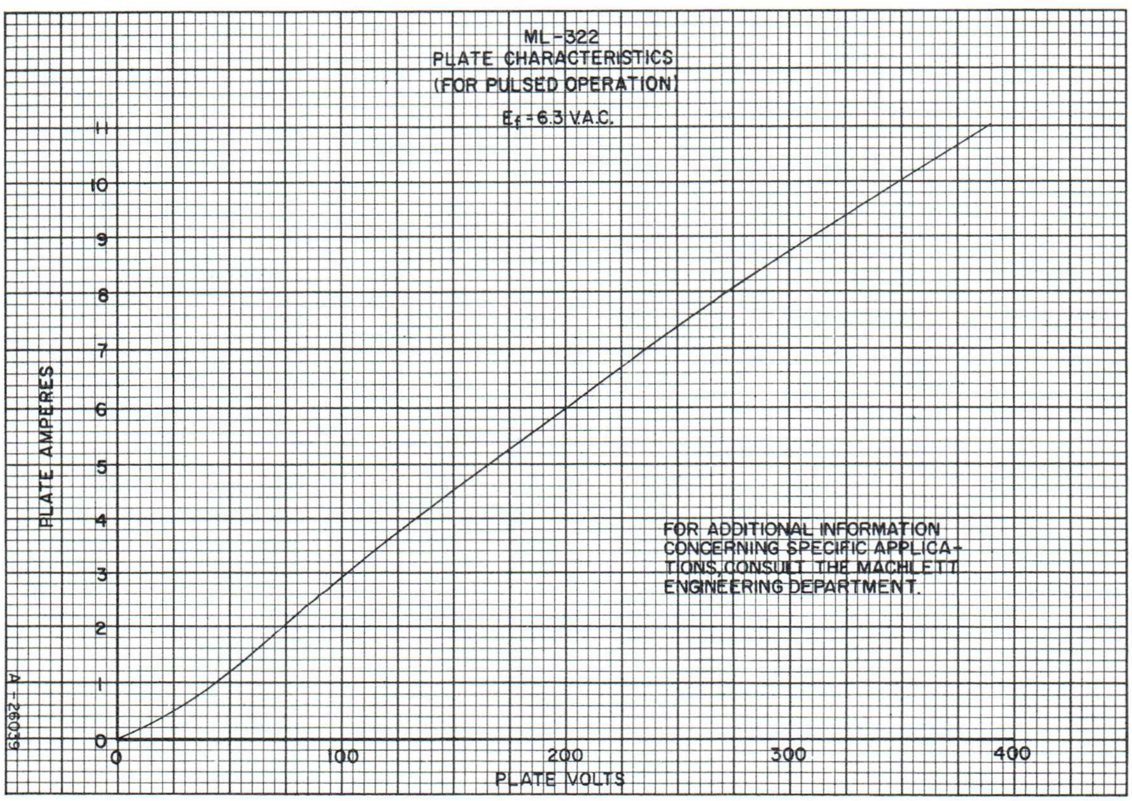
Peak Inverse Voltage	800	Volts
Peak Plate Current	600	mAdc
Average Plate Current	100	mAdc
Average Plate Dissipation	15	watts*

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.



ML-322
PLATE CHARACTERISTICS
Ef=6.3 VOLTS, AC
PLATE CURRENT IN MILLIAMPERES
600
500
400
300
200
100
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
PLATE VOLTS
A-8979



ML-322
PLATE CHARACTERISTICS
(FOR PULSED OPERATION)
Ef = 6.3 V.A.C.
PLATE AMPERES
11
10
9
8
7
6
5
4
3
2
1
0
0 100 200 300 400
PLATE VOLTS
FOR ADDITIONAL INFORMATION CONCERNING SPECIFIC APPLICATIONS CONSULT THE MACHLETT ENGINEERING DEPARTMENT.
A-26039

ML-518

Frequency stable operation within 2 seconds*. 600 volt anode.

DESCRIPTION

The **ML-518** is a ruggedized, high-mu planar triode of ceramic and metal construction, designed for use as an oscillator, frequency multiplier, or amplifier in radio transmitting service at frequencies up to 2500 Mc. The tube may be operated at higher frequencies with reduced ratings.

In addition to low interelectrode capacitance, high transconductance and high-mu, this tube incorporates design features which help to assure frequency stable operation even under adverse ambient temperature and varying plate dissipation conditions. The cathode is an indirectly heated oxide-coated disc. The anode is forced-air cooled. Anode adaptors for heatsink cooling can be provided upon request.

TENTATIVE

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.0	Volts †
Heater Current (AC or DC) at 6.0 Volts	1.0	Amp
Cathode Heating Time, minimum	60	secs
Amplification Factor	100	
Transconductance (I_b=70 mA, E_b=600 V)	25,000	μmhos
Interelectrode Capacitances (without heater voltage):		
Grid-Plate	4.5	μμf
Grid-Cathode	6.60	μμf
Plate-Cathode, maximum	.06	μμf
Frequency for Maximum Ratings	2500	Mc

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced-Air ‡	
Maximum Anode Temperature	250	°C
Net Weight, approximate	2.5	oz.

MAXIMUM RATINGS

RF Power Amplifier and Oscillator

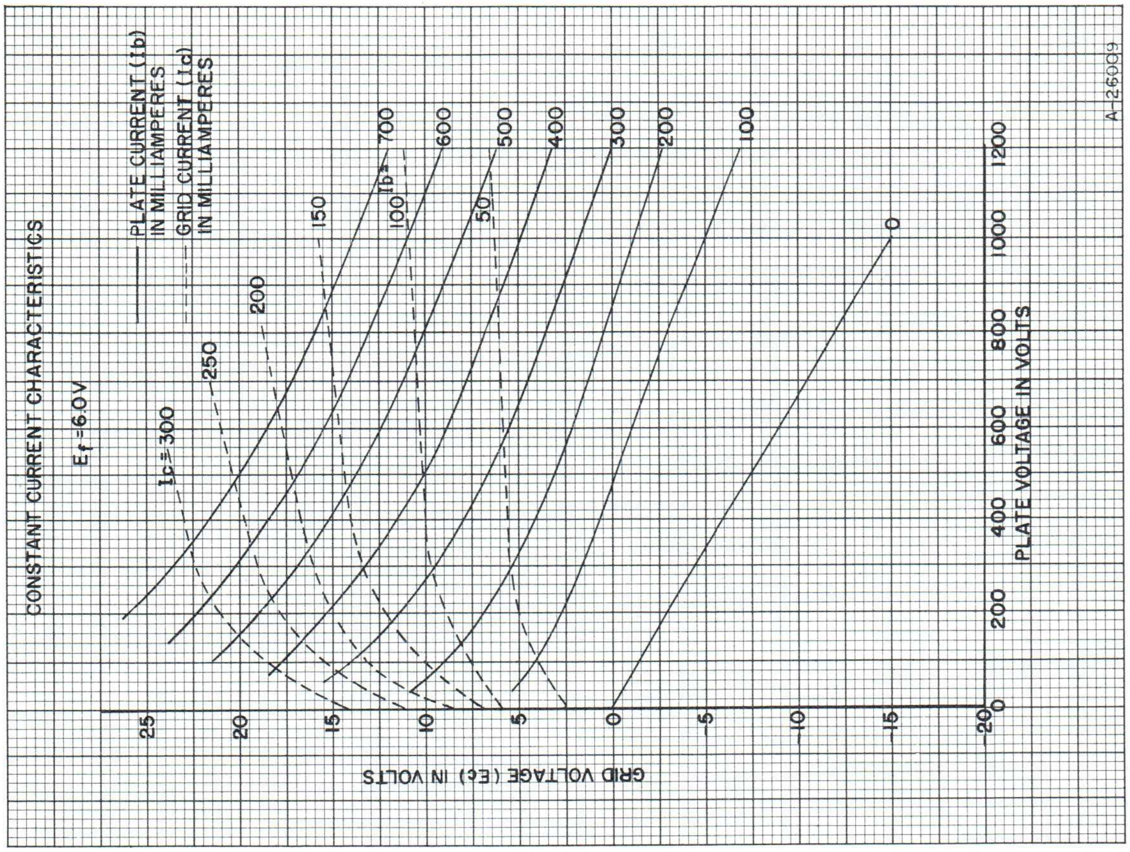
Maximum Ratings, Absolute Values

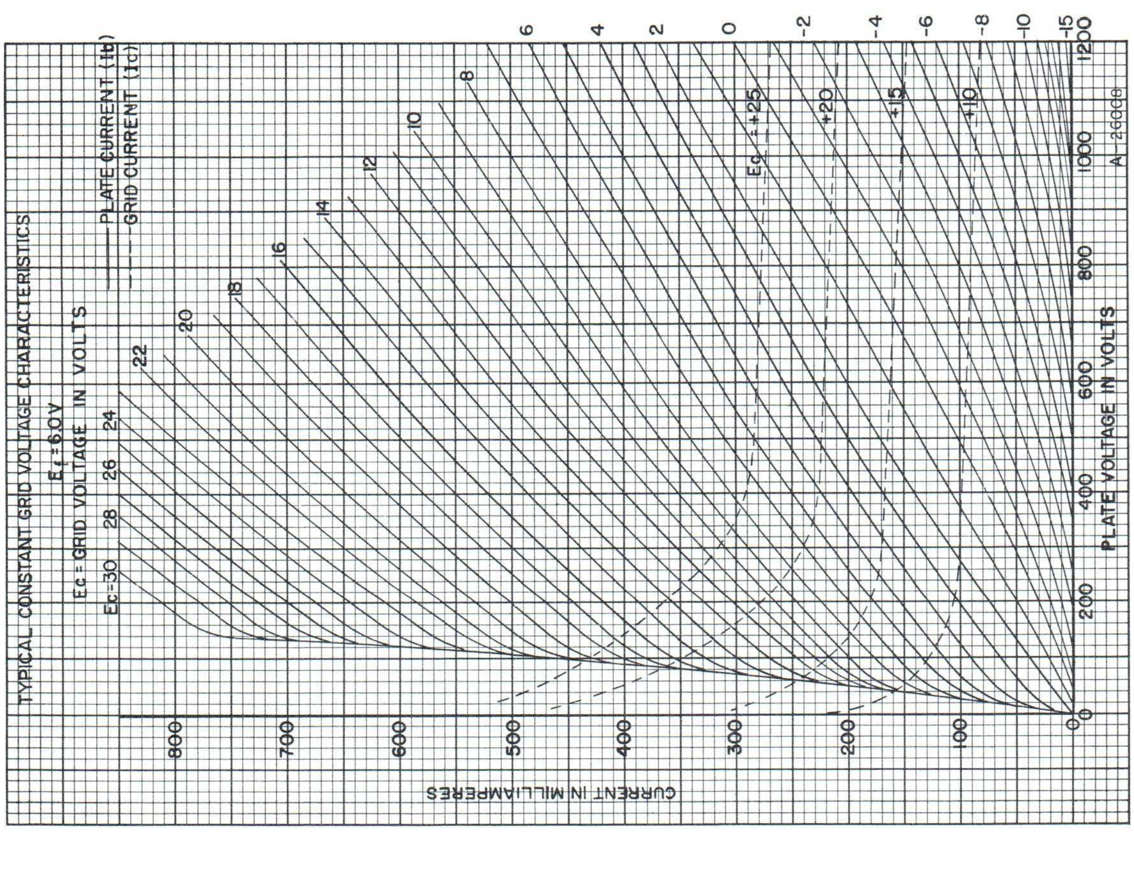
DC Plate Voltage	600	Volts
DC Grid Voltage	−150	Volts
DC Cathode Current	125	mA
DC Grid Current	30	mA
Peak Positive RF Grid-Cathode Voltage	30	volts
Peak Negative RF Grid-Cathode Voltage	−400	volts
Plate Dissipation (Forced-air cooling or with appropriate heatsink)	100	Watts
Grid Dissipation	2	Watts

†See Application Note, page 16, for optimum heater voltage.

‡See Application Notes, page 16 and also air cooling curves, page 83.

* Or longer, depending on circuitry.


CONSTANT CURRENT CHARACTERISTICS
E_f = 6.0V
PLATE CURRENT (Ib) IN MILLIAMPERES
GRID CURRENT (Ic) IN MILLIAMPERES
Ic = 300
250
200
150
100
50
Ib = 700
600
500
400
300
200
100
0
GRID VOLTAGE (Ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-26009


TYPICAL CONSTANT GRID VOLTAGE CHARACTERISTICS
E_f = 6.0V
Ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (Ib)
GRID CURRENT (Ic)
Ec = 30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-15
Ec = +25
+20
+15
+10
CURRENT IN MILLIAMPERES
PLATE VOLTAGE IN VOLTS
A-26008

ML-6442

Plate-pulsed oscillator service.

DESCRIPTION

The **ML-6442** is a metal-ceramic envelope, medium-mu triode of the planar-electrode type designed specifically for use as a plate-pulsed oscillator and amplifier at frequencies up to about 5000 Mc. It can also be used as a c-w oscillator, r-f power amplifier or frequency multiplier at frequencies up to 2500 Mc. Features include short electron transit time, low inter-electrode capacitances and high transconductance. Lead inductances and r-f losses are minimized by a compact, rugged metal-ceramic construction with ring type seals, making the tube ideally suited to cavity type circuits as well as for parallel line operation. The cathode is an indirectly-heated, oxide-coated disc. The heater is insulated from the cathode permitting this tube to be used in series-string circuitry. The anode is cooled by conduction and convection and is capable of dissipating 8 watts.

Electrical

Cathode	Indirectly Heated
Heater Voltage	6.3 volts†
Heater Current, AC or DC	0.9 Amp
Cathode Heating Time for Pulse Operation, minimum	60 Seconds
Amplification Factor	50
Direct Interelectrode Capacitances, approximate	
Grid-Plate	2.3 μμf
Grid-Cathode, Eh = 0	5.10 μμf
Plate-Cathode, maximum, Eh = 0	0.045 μμf

Mechanical

Mounting Position	Optional
Type of Cooling	Conduction and convection
Envelope Temperature, maximum	175 °C
Net Weight, approximate	1 ounce

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Plate-Pulsed Amplifier and Oscillator — Class C

Maximum Ratings, Absolute Values

For a Maximum Conducting Period of 5 Microseconds in any 5000 Microsecond Interval.*

The tube shall not be grid pulsed beyond the Class C Telegraphy ratings.

Peak Positive-Pulse Plate-Supply Voltage	3000	volts
Peak Negative-Pulse Grid-Bias Voltage	100	volts
Peak Plate Current from Pulse Supply†	2.5	amps
Peak Rectified Grid Current	1.25	amps
DC Plate Current	2.5	mA
DC Grid Current	1.25	mA
Plate Input	7.5	Watts
Plate Dissipation	7.5	Watts
Pulse Duration	2.0	μsec
Cathode Heating Time	60	Seconds
Peak Heater-Cathode Voltage		
Heater Negative with Respect to Cathode	90	volts
Heater Positive with Respect to Cathode	90	volts
Frequency	5000	Mc
Duty Factor*	0.001	

Typical Operation — With Rectangular Wave Shape

Plate Pulsed Self-Excited Oscillator at 3500 Mc

Duty Factor	0.001	
Peak Positive-Pulse Plate-Supply Voltage	3000	volts
Peak Negative-Pulse Grid Bias Voltage, approx.	75	volts
Grid Bias Resistor, approximate	50	ohms
Peak Current from Pulse Supply	2.5	amps
Peak Rectified Grid Current	1.25	amps
DC Plate Current	2.5	mA
DC Grid Current	1.25	mA
Useful Power Output at Peak of Pulse, approx.	2.0	kW
Pulse Duration	1.0	μsec
Pulse Repetition Rate	1000	pps
Heater Voltage	6.0	Volts

* For applications above a duty factor of 0.001, contact the Machlett Engineering Department for recommendations.

† The regulation and/or series plate supply impedance shall be such as to limit the instantaneous peak current, with the tube considered as a short circuit, to a maximum of 10 times the specified maximum current rating.

Radio-Frequency Power Amplifier and Oscillator— Class C Telephony

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

Maximum Ratings, Absolute Values

DC Plate Voltage	275	Volts
DC Grid Voltage	−50	Volts
DC Plate Current	35	mA
DC Grid Current	15	mA
Plate Input	9.5	Watts
Plate Dissipation	6.0	Watts
Peak Heater-Cathode Voltage		
Heater Negative with Respect to Cathode	90	volts
Heater Positive with Respect to Cathode	90	volts
Frequency	2500	Mc

Radio-Frequency Power Amplifier and Oscillator— Class C Telegraphy

Key-down conditions per tube without amplitude modulation‡

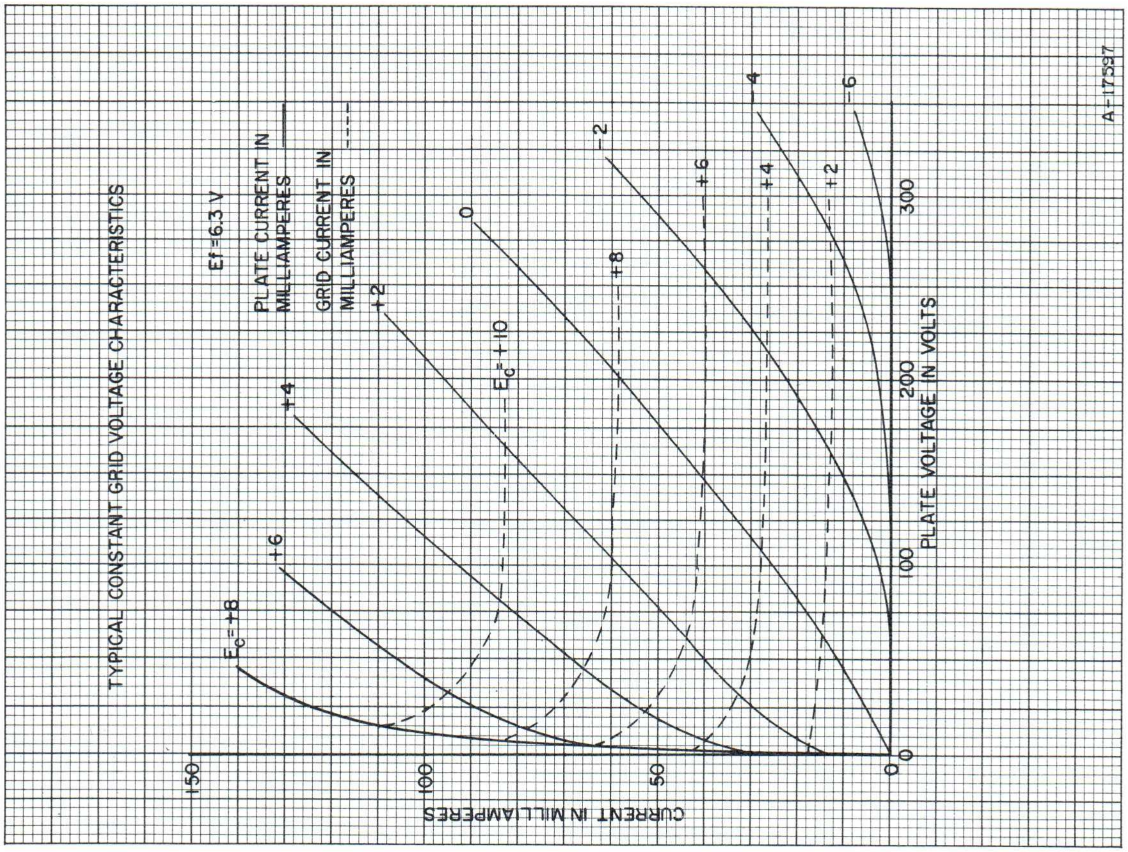
Maximum Ratings, Absolute Values

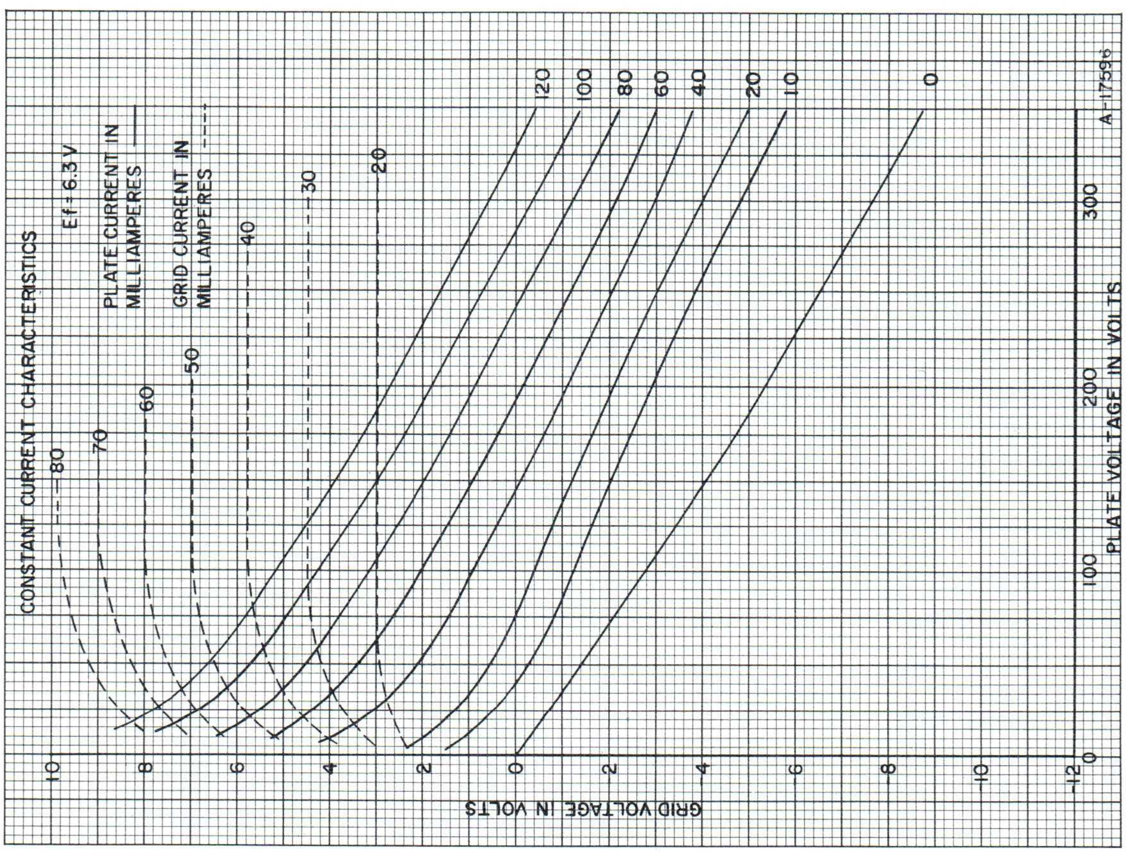
DC Plate Voltage	350	Volts
DC Grid Voltage	−50	Volts
DC Plate Current	35	mA
DC Grid Current	15	mA
Plate Power Input	12	Watts
Plate Dissipation	8	Watts
Peak Heater-Cathode Voltage		
Heater Negative with Respect to Cathode	90	volts
Heater Positive with Respect to Cathode	90	volts
Frequency	2500	Mc

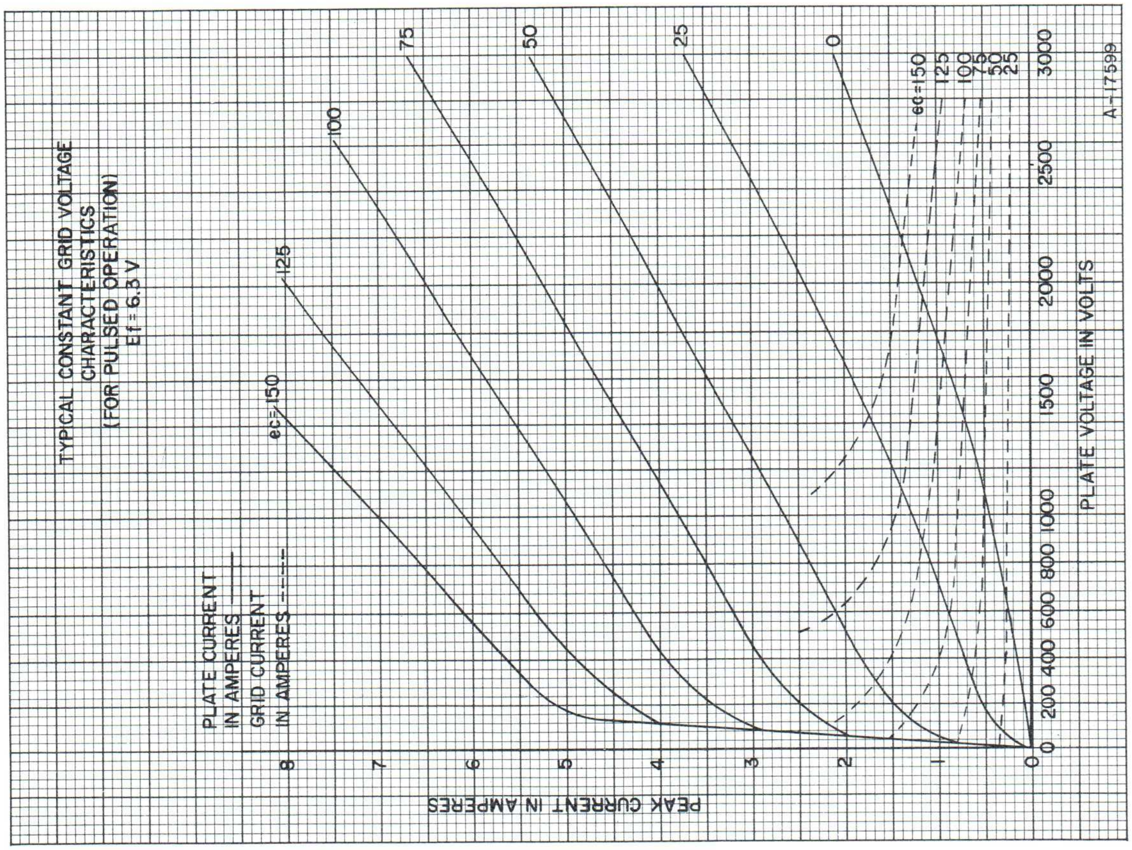
‡ Modulation essentially negative may be used if the positive peak of the audio-frequency envelope does not exceed 115 percent of the carrier conditions.

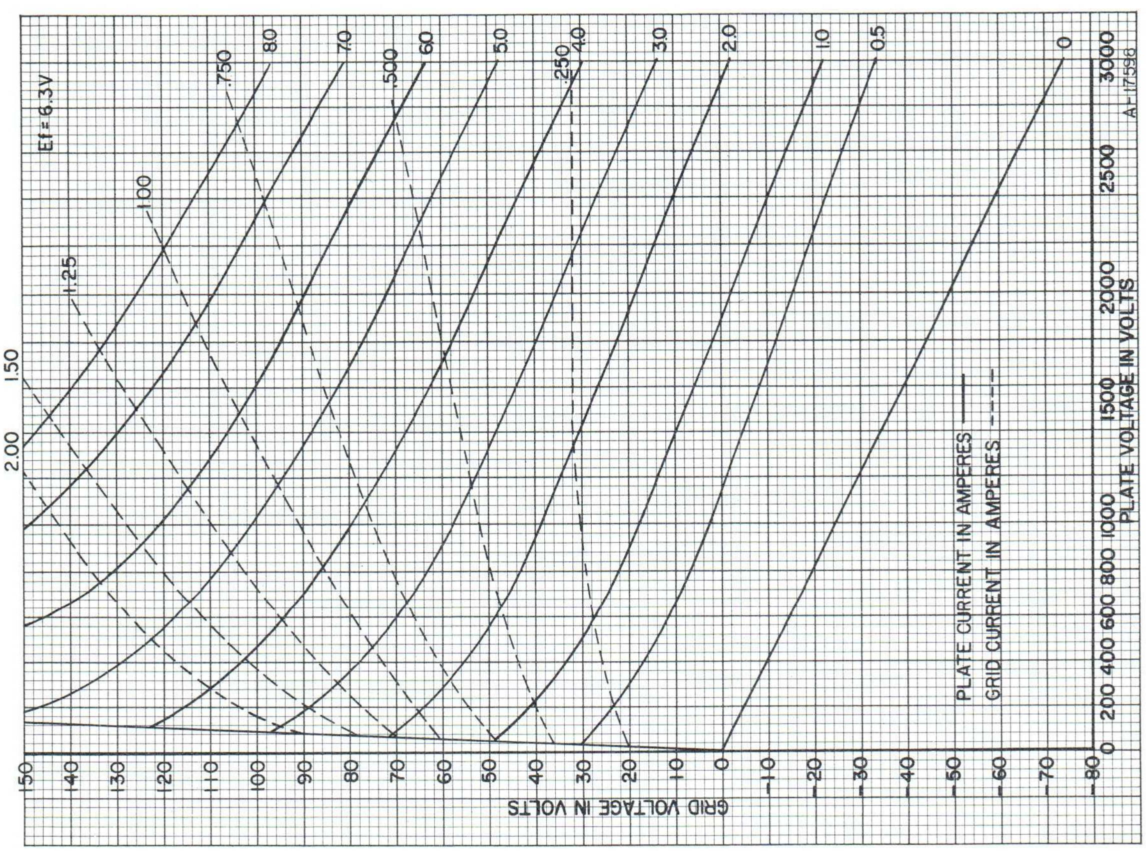
CHARACTERISTIC RANGE VALUES FOR EQUIPMENT DESIGN

Class A_1 Amplifier	Min.	Max.	
Plate Voltage	——	350	Volts
DC Grid Bias, approximate	−2.5	−5.75	Vdc
Amplification Factor, approximate, Ec/Ib = 35 mAdc	35	65	
Transconductance	13500	19000	μmhos
Plate Current	——	35	mAdc
Grid-Plate Capacitance	2.10	2.45	μμf
Grid-Cathode Capacitance, Eh = 0	4.60	5.45	μμf
Plate-Cathode Capacitance, Eh = 0	——	0.045	μμf


TYPICAL CONSTANT GRID VOLTAGE CHARACTERISTICS
Ef = 6.3 V
PLATE CURRENT IN MILLIAMPERES
GRID CURRENT IN MILLIAMPERES
E_c = +8
+6
+4
+2
0
-2
-4
-6
E_c = +10
+8
+6
+4
+2
150
100
50
0
CURRENT IN MILLIAMPERES
0
100
200
300
PLATE VOLTAGE IN VOLTS
A-17597


CONSTANT CURRENT CHARACTERISTICS
Ef = 6.3 V
PLATE CURRENT IN MILLIAMPERES
GRID CURRENT IN MILLIAMPERES
80
70
60
50
40
30
20
120
100
80
60
40
20
10
0
10
8
6
4
2
0
2
4
6
8
10
12
GRID VOLTAGE IN VOLTS
0
100
200
300
PLATE VOLTAGE IN VOLTS
A-17596





CONSTANT CURRENT CHARACTERISTICS FOR PULSED OPERATION

ML-6771

General purpose application.

DESCRIPTION

The **ML-6771** is a high-mu, planar triode of ceramic-and-metal construction, particularly designed for use in grounded-grid service as a radio-frequency amplifier, oscillator, or frequency multiplier for frequencies up to 4000 Mc. The tube features low interelectrode capacitances, low electrode lead inductance, short electron transit time and rugged, compact coaxial construction. These features make the tube well suited for efficient operation in line-type and lumped-constant circuits at the lower frequencies as well as in cavity resonators at higher frequencies. The tube employs an indirectly heated, oxide-coated disc as a cathode. The heater is electrically separated from the cathode, permitting the use of comparatively simple circuits. The anode is cooled by conduction and convection.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.3 Volts †
Heater Current at 6.3 Volts (AC or DC)	.57 Amperes
Cathode Heating Time, minimum	60 Seconds
Amplification Factor	90
Transconductance	23,000 μmhos
Interelectrode Capacitances (without heater voltage)	
Grid-Plate	2.0 μμf
Grid-Cathode	4.05 μμf
Plate to Cathode	0.018 μμf
Frequency for Maximum Ratings	4000 Mc

Mechanical

Mounting Position	Optional
Type of Cooling	Conduction and Convection*
Envelope Temperature, maximum	175 °C
Net Weight, approximate	1 Ounce

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATION

Radio-Frequency Amplifier — Class A

Maximum Ratings, Absolute Values

Heater Voltage	5.7 ±5% Volts
DC Plate Voltage	300 Volts
DC Grid Voltage	−25 Volts
DC Plate Current	25 mA
Plate Dissipation	6.25 Watts
Peak Heater-Cathode Voltage	
Heater Negative	90 volts
Heater Positive	90 volts
Maximum Grid-Circuit Resistance	0.5 Megohms

Radio-Frequency Power Amplifier and Oscillator

Key-down conditions without amplitude modulation

Maximum Ratings, Absolute Values

Heater Voltage	*
DC Plate Voltage	275 Volts
DC Plate Current	25 mA
DC Grid Voltage	−25 Volts
DC Grid Current	8 mA
Plate Power Input	7 Watts
Plate Dissipation	6.25 Watts
Peak Heater-Cathode Voltage	
Heater Negative	90 volts
Heater Positive	90 volts
Maximum Grid-Circuit Resistance	0.1 Megohms

Typical Operating Conditions

C-W Radio-Frequency Oscillator, 4000 Mc

Heater Voltage	5.0 Volts
DC Plate Voltage	250 Volts
DC Plate Current	25 mA
DC Grid Voltage	−1.7 Volts
DC Grid Current	0.6 mA
CW Power Input	300 Milliwatts

Radio-Frequency Power Amplifier and Oscillator Class C Telephony

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

Maximum Ratings, Absolute Values

Heater Voltage	*
DC Plate Voltage	250 Volts
DC Plate Current	22 mA
DC Grid Voltage	−25 Volts
DC Grid Current	8 mA
Plate Input	5.5 Watts
Plate Dissipation	5.0 Watts
Peak Heater-Cathode Voltage	
Heater Negative	90 volts
Heater Positive	90 volts
Maximum Grid-Circuit Resistance	0.1 Megohms

Radio-Frequency Multiplier

Maximum Ratings, Absolute Values

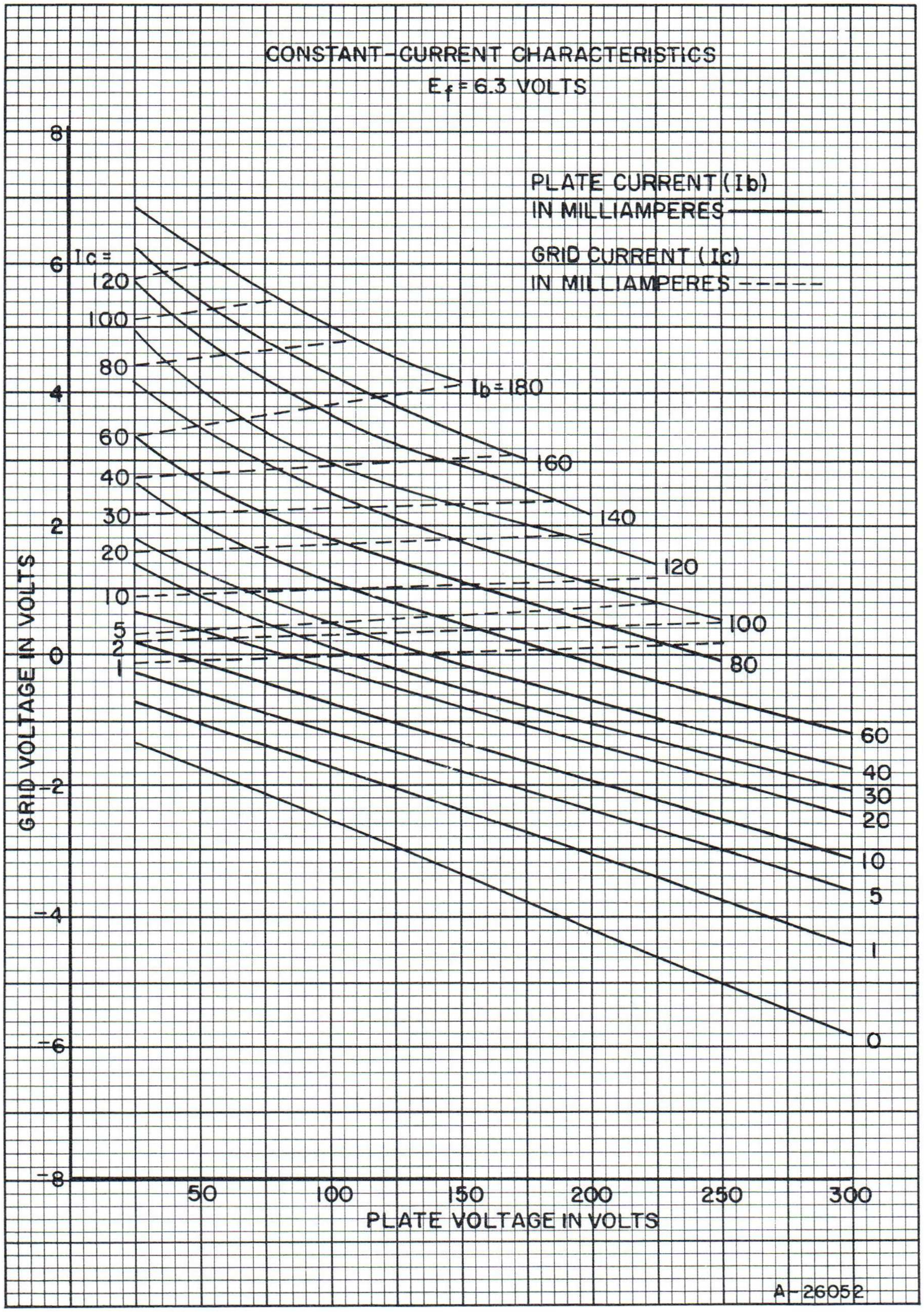
Heater Voltage	*
DC Plate Voltage	250 Volts
DC Plate Current	20 mA
DC Grid Voltage	−50 Volts
DC Grid Current	5 mA
Plate Input	5.0 Watts
Plate Dissipation	5.0 Watts
Peak Heater-Cathode Voltage	
Heater Negative	90 volts
Heater Positive	90 volts
Maximum Grid-Circuit Resistance	0.1 Megohms

Typical Operating Conditions

Radio-Frequency Doubler, 500-1000 Mc

Heater Voltage	5.7 Volts
DC Plate Voltage	250 Volts
DC Plate Current	20 mA
DC Grid Voltage	10 Volts
DC Grid Current	5 mA
RF Power Input	300 Milliwatts
RF Power Output	2.0 Watts

* The correct value of heater voltage is dependent upon the particular operating conditions and frequency. For particular applications consult the Machlett Engineering Department.


CONSTANT-CURRENT CHARACTERISTICS
Ef = 6.3 VOLTS
PLATE CURRENT (Ib) IN MILLIAMPERES
GRID CURRENT (Ic) IN MILLIAMPERES
Ic =
120
100
80
60
40
30
20
10
5
2
1
Ib = 180
160
140
120
100
80
60
40
30
20
10
5
1
0
GRID VOLTAGE IN VOLTS
8
6
4
2
0
-2
-4
-6
-8
50
100
150
200
250
300
PLATE VOLTAGE IN VOLTS
A-26052

ML-7209

High shock rating.

DESCRIPTION

The **ML-7209** is a high-mu triode of the planar-electrode type designed for use as a plate-pulsed oscillator, frequency multiplier, or power amplifier in radio transmitting service from low frequency to 3000 Mc. Features include low interelectrode capacitances, high transconductance and great mechanical strength. Lead inductances and r.f. losses are minimized by a compact, rugged coaxial construction, making the tube ideally suited to cavity type circuits as well as for parallel line operation. The cathode is an indirectly-heated, oxide-coated disc. The anode is forced-air cooled. The **ML-7209** is a direct replacement for the **ML-381** but is constructed to withstand more severe conditions of shock and vibration.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.0	Volts†
Heater Current (AC or DC) at 6.0 volts	1.0	Amp
Heater Heating Time, minimum	60	sec
Amplification Factor	100	
Transconductance (I_b = 70 mA, E_b = 600 v)	25000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.01	$\mu\mu f$
Grid-Cathode	6.60	$\mu\mu f$
Plate-Cathode, maximum	0.035	$\mu\mu f$
Duty Factor	.0033	‡
Maximum Pulse Length	5	μsecs‡
Frequency for Maximum Ratings	3000	Mc

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Anode Temperature	200	°C
Net Weight	2¼	oz.

†See Application Note, page 16, for optimum heater voltage.

‡For applications requiring longer pulse lengths or higher duty factors, consult the Machlett Engineering Department.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Plate-Pulsed Oscillator and Amplifier—Class C

Maximum Ratings, Absolute Values		
For a pulse length of	5	μsec
Duty Factor	3.3×10^{-3}	
Peak Plate Pulse Supply Voltage	3500	volts
DC Grid Bias Voltage‡	-150	volts
Peak Plate Current from Pulse Supply	3	amps
Average Plate Current	10	mA
Average Grid Current	5	mA
Average Plate Dissipation	35	watts
Average Grid Dissipation	2	watts
Typical Operation: 2500 Mc Oscillator		
Pulse Length	5	μsec
Duty Factor	3.0×10^{-3}	
Peak Plate Pulse Supply Voltage	3500	volts
DC Grid Bias Voltage	-100	volts
Peak R-F Grid Voltage	340	volts
Peak R-F Plate Voltage	2500	volts
Peak Plate Current from Pulse Supply	3	amps
Average Plate Current	9	mA
Average Grid Current	3	mA
Driving Power During Pulse, Approximate	450	watts
Useful Power Output at Peak of Pulse, Approx.	2200	watts
Pulse Recurrence Rate	660	pps

Frequency Doubler—Class C Telegraphy

Maximum Ratings, Absolute Values		
For a pulse length of	5	μsec
Duty Factor	3.3×10^{-3}	
Peak Plate Pulse Supply Voltage	3500	volts
Grid Bias Voltage (from cathode resistor)‡	-200	volts
Peak Cathode Current	3	amps
Average Plate Current	6.5	mA
Average Grid Current	2.0	mA
Average Plate Input	25	watts
Average Plate Dissipation	25	watts
Average Grid Dissipation	1.0	watt
Typical Operation — Doubler 600 to 1200 Mc		
Pulse Length	3	μsec
Duty Factor	3.0×10^{-3}	
Filament Voltage (See Application Notes)	5.5	volts
Peak Plate Pulse Supply Voltage	3500	volts
Grid Bias Voltage (from cathode resistor)	-190	volts
Cathode Resistor	160	ohms
Peak Plate Current	1.2	amps
Driving Power During Pulse, Approximate	600	watts
Useful Power Output at Peak of Pulse, Approx.	1200	watts
Average Plate Dissipation	9	watts

‡The maximum instantaneous peak grid-cathode voltage should be within the range of +250 to —750 volts.

Characteristic Range Values for Equipment Design

	Min.	Max.	
Filament Current at 6.0 volts (Note 1)	0.90	1.05	A
Plate Current (Note 2)	60	95	mAdc
Cut-off Bias (Note 3)	—	-15	Vdc
Transconductance	20,000	30,000	
Grid-Plate Capacitance (Note 4)	1.86	2.16	μμf
Grid-Cathode Capacitance (Note 4)	5.60	7.60	μμf
Plate-Cathode Capacitance (Note 4)	—	.035	μμf
Plate Tuning Range (Note 5)	1980	2020	Mc

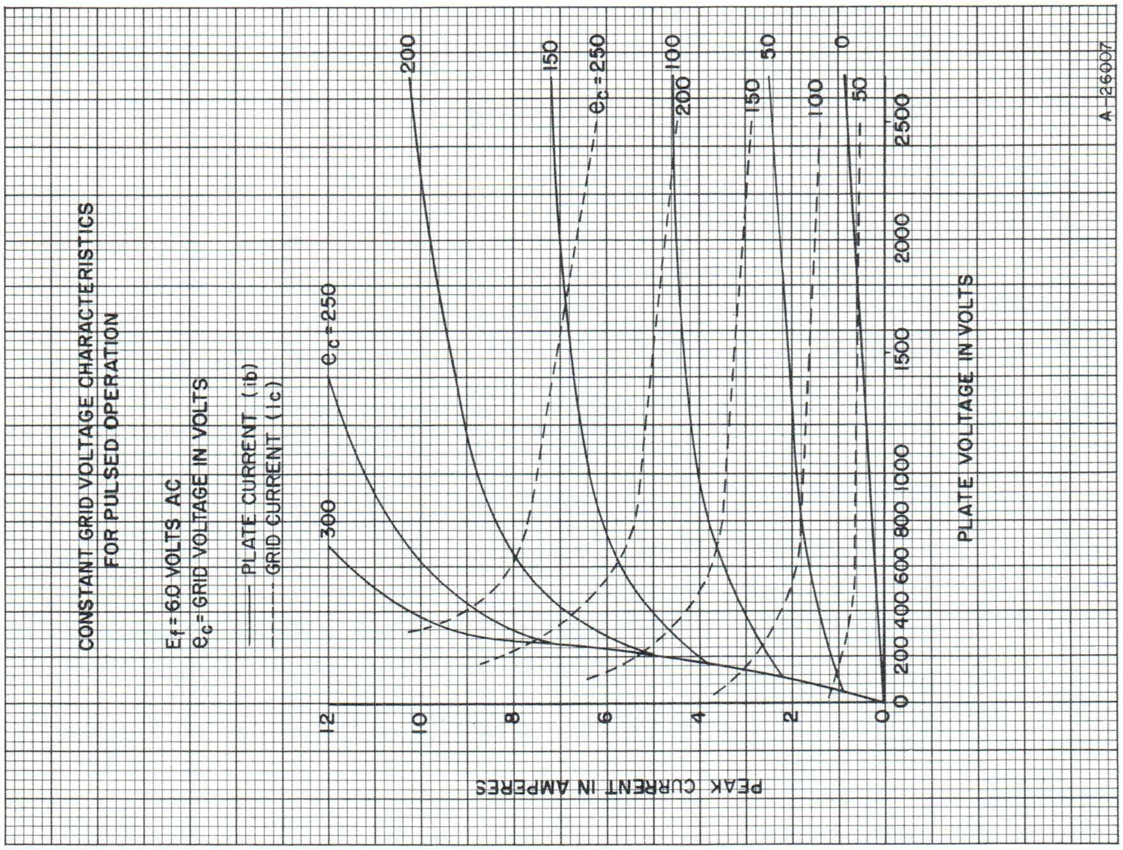
Note 1 — For reduced filament voltage see "Heater Voltage" section under "Application Notes".

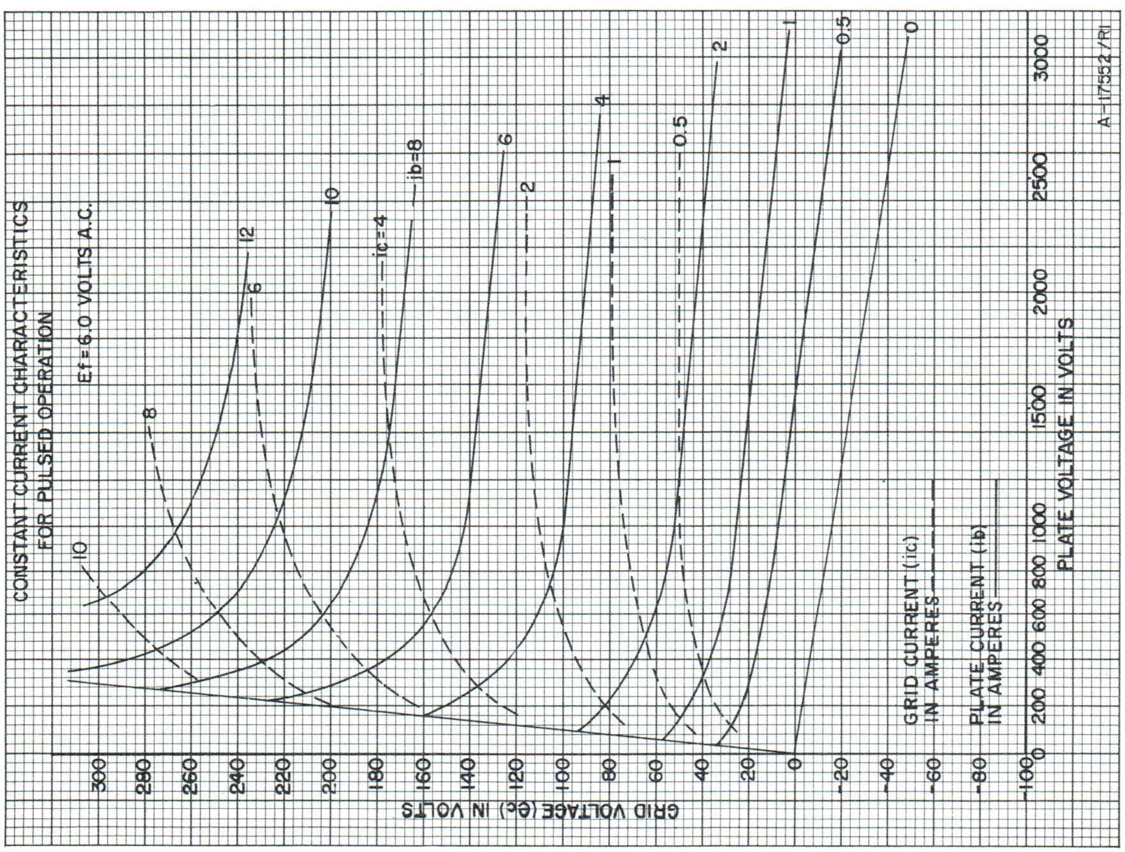
Note 2 — Measure at a plate voltage of 600 volts and a cathode-bias resistor of 30 ohms.

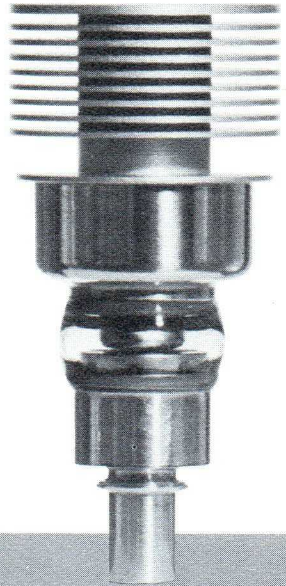
Note 3 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

Note 4 — Capacitance measurements are with the tube cold. When the filament is heated to proper operating temperature the grid-cathode capacitance will increase by about 1 μμf due to thermal expansion of the cathode.

Note 5 — With a plate-grid coaxial cavity of fixed dimensions, all tubes will resonate within the specified frequency range.


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS AC
ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
PEAK CURRENT IN AMPERES
PLATE VOLTAGE IN VOLTS
A-26007


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS A.C.
GRID CURRENT (ic) IN AMPERES
PLATE CURRENT (ib) IN AMPERES
GRID VOLTAGE (ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-17552/R1



ML-7210

12 second warm-up cathode.

DESCRIPTION

The **ML-7210** is a quick-heating cathode, high-mu planar triode designed for use as a plate-pulsed or CW oscillator, frequency multiplier or power amplifier in radio transmitting service from low frequency to 3000 Mc. The tube may be operated at higher frequencies with reduced ratings. A special feature of this tube is its quick-heating cathode, which permits tube operation in as little as 12 seconds after energizing the heater. Other features include low interelectrode capacitances, high transconductance and great mechanical strength. Lead inductances and r-f losses are minimized by a compact, rugged construction with ring-type seals, making the tube ideally suited to cavity-type circuits as well as for parallel-line operation. The cathode is an indirectly-heated, oxide-coated disc. The anode is forced-air cooled.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.3	Volts†
Heater Current (AC or DC) at 6.3 Volts	0.85	Amp
Heater Heating Time, minimum	12	secs
Amplification Factor	75	
Transconductance (I_b = 70 mA, E_b = 600 v)	17,000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.0	μμf
Grid-Cathode	5.0	μμf
Plate-Cathode, maximum	0.040	μμf
Duty Factor	.0025	‡
Maximum Pulse Length	3	μsec‡
Frequency for Maximum Ratings	3000	Mc

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Anode Temperature	200	°C
Net Weight	2¼	oz.

†See Application Note, page 16, for optimum heater voltage.

‡For applications requiring longer pulse lengths or higher duty factors, consult the Machlett Engineering Department.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

R-F Power Amplifier and Oscillator

Key-down conditions per tube without amplitude modulation‡

Maximum Ratings, Absolute Values

D-C Plate Voltage	1000	volts
D-C Grid Voltage	-150	volts
D-C Cathode Current	95	mA
D-C Grid Current§	30	mA
Peak Positive RF Grid Voltage	30	volts
Peak Negative RF Grid Voltage	-400	volts
Plate Dissipation† (Forced-air Cooling)	100	watts
Grid Dissipation	1.5	watts

Plate-Pulsed Oscillator and Amplifier Class C

Maximum Ratings, Absolute Values

Pulse Length	3	μsec
Duty Factor	0.0025	
Peak Plate Pulse Supply Voltage	3500	volts
DC Grid Bias Voltage*	-150	volts
Peak Plate Current from Pulse Supply	2.8	amps
Average Plate Current	7.0	mA
Average Grid Current	3.0	mA
Average Plate Dissipation	25	watts
Average Grid Dissipation	1.5	watts

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

§See "Application Notes" on "Determination of Proper Grid Drive".

†Refer to "Cooling" under "Application Notes".

*The maximum instantaneous peak grid-cathode voltage should be within the range of +250 to —500 volts.

Characteristic Range Values for Equipment Design

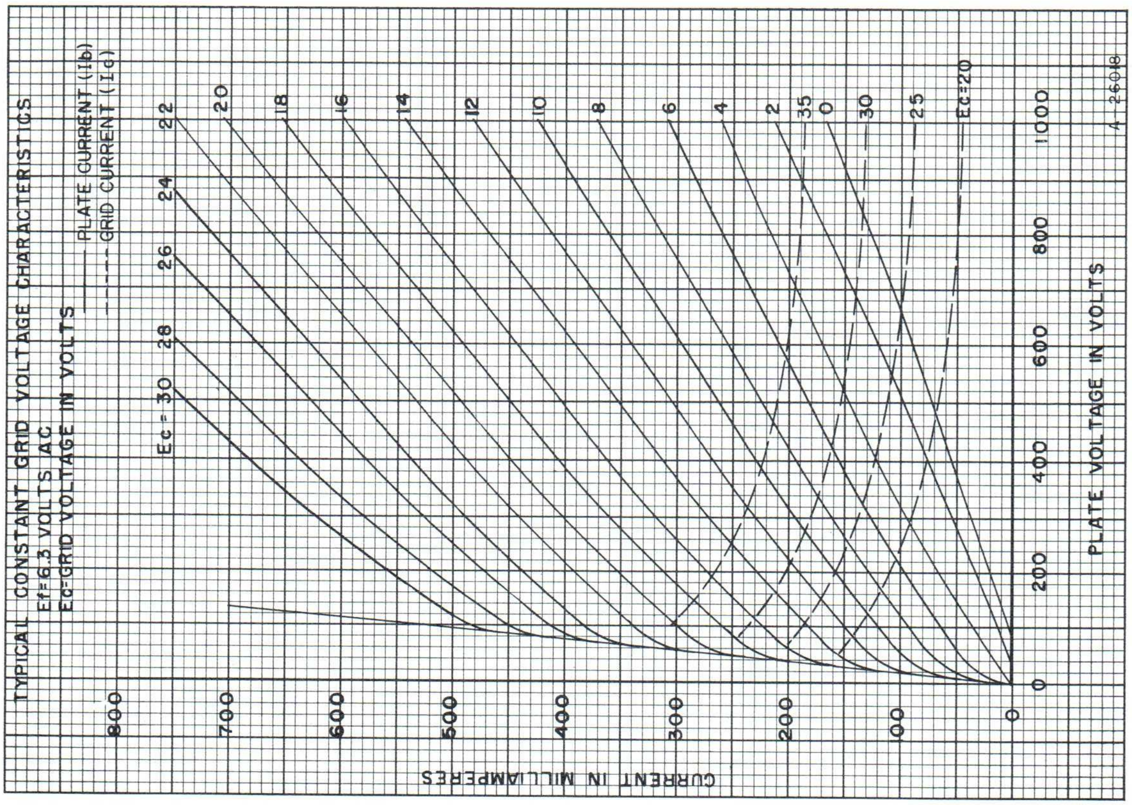
	Min.	Max.	
Filament Current at 6.3 volts	.75	.95	A
Plate Current (Note 1)	55	90	mAdc
Cut-off bias (Note 2)	—	-20	volts
Transconductance	12,000	22,000	μmhos
Grid-Plate Capacitance (Note 3)	1.84	2.16	μμf
Grid-Cathode Capacitance (Note 3)	4.00	6.00	μμf
Plate Tuning Range (Note 4)	1970	2030	Mc

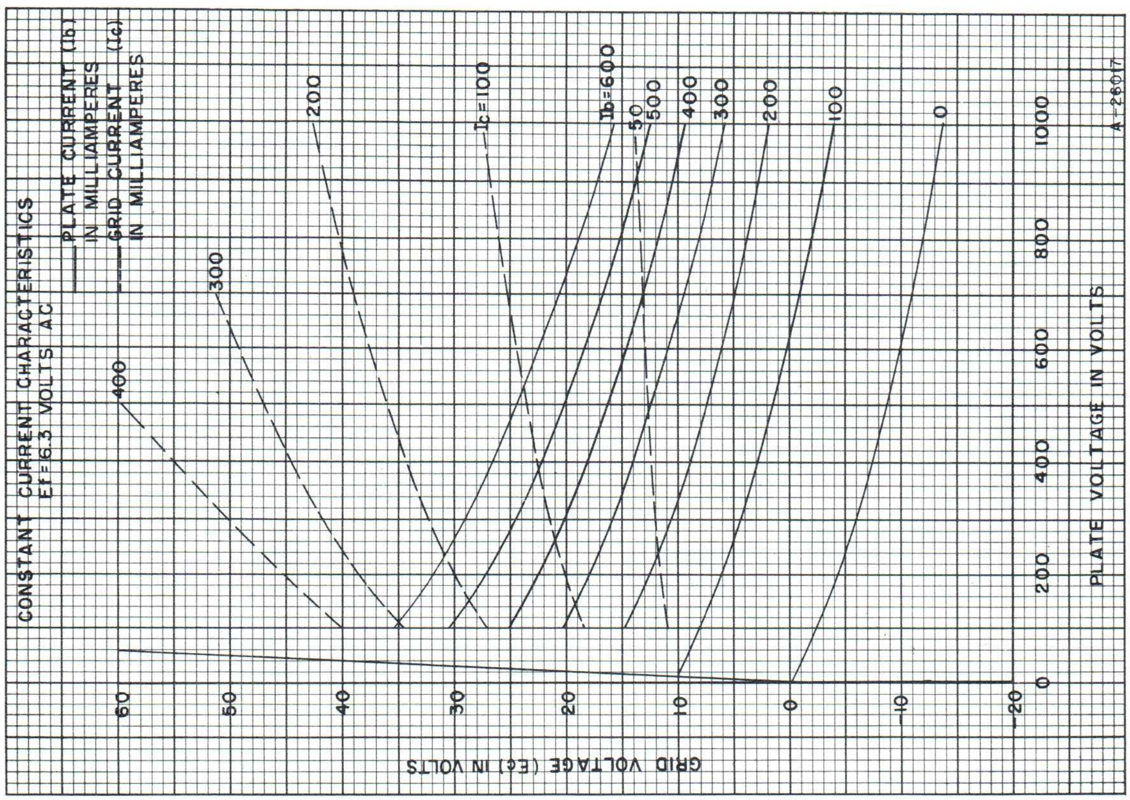
Note 1 — Measured at a plate voltage of 600 volts and a cathode-bias resistor of 30 ohms.

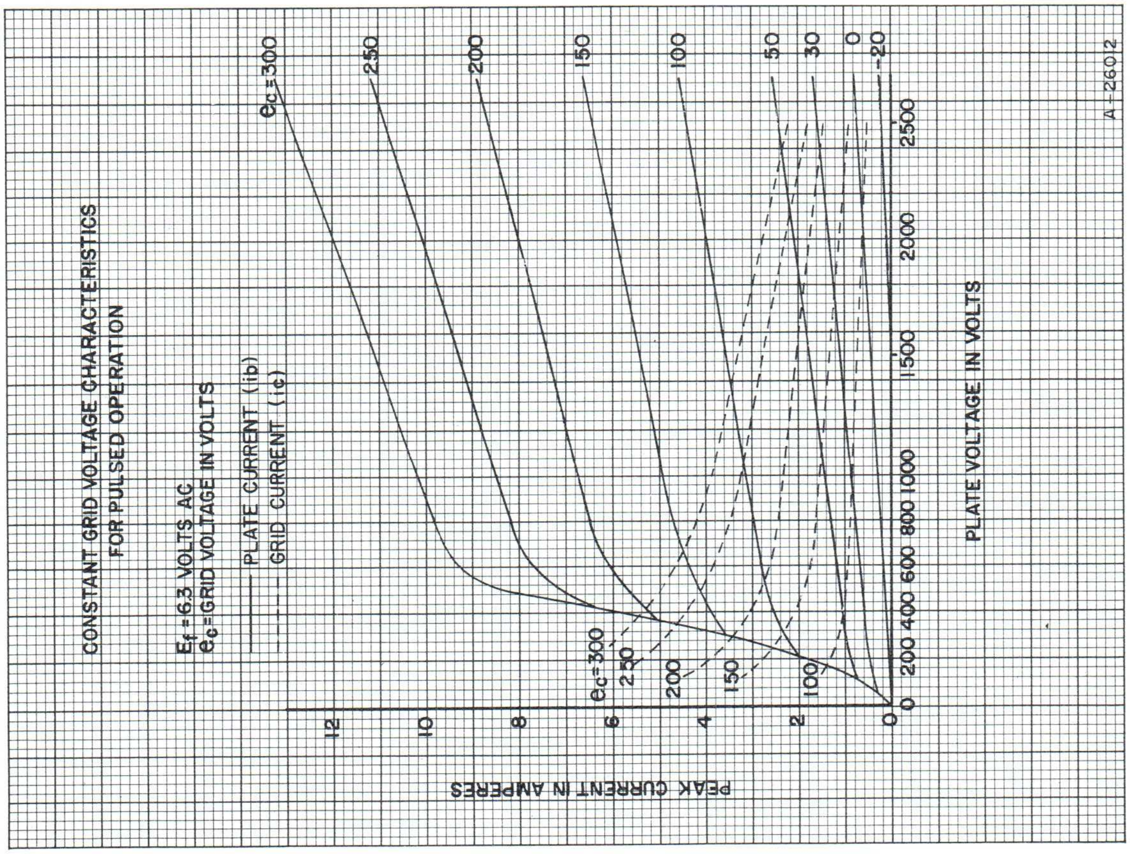
Note 2 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

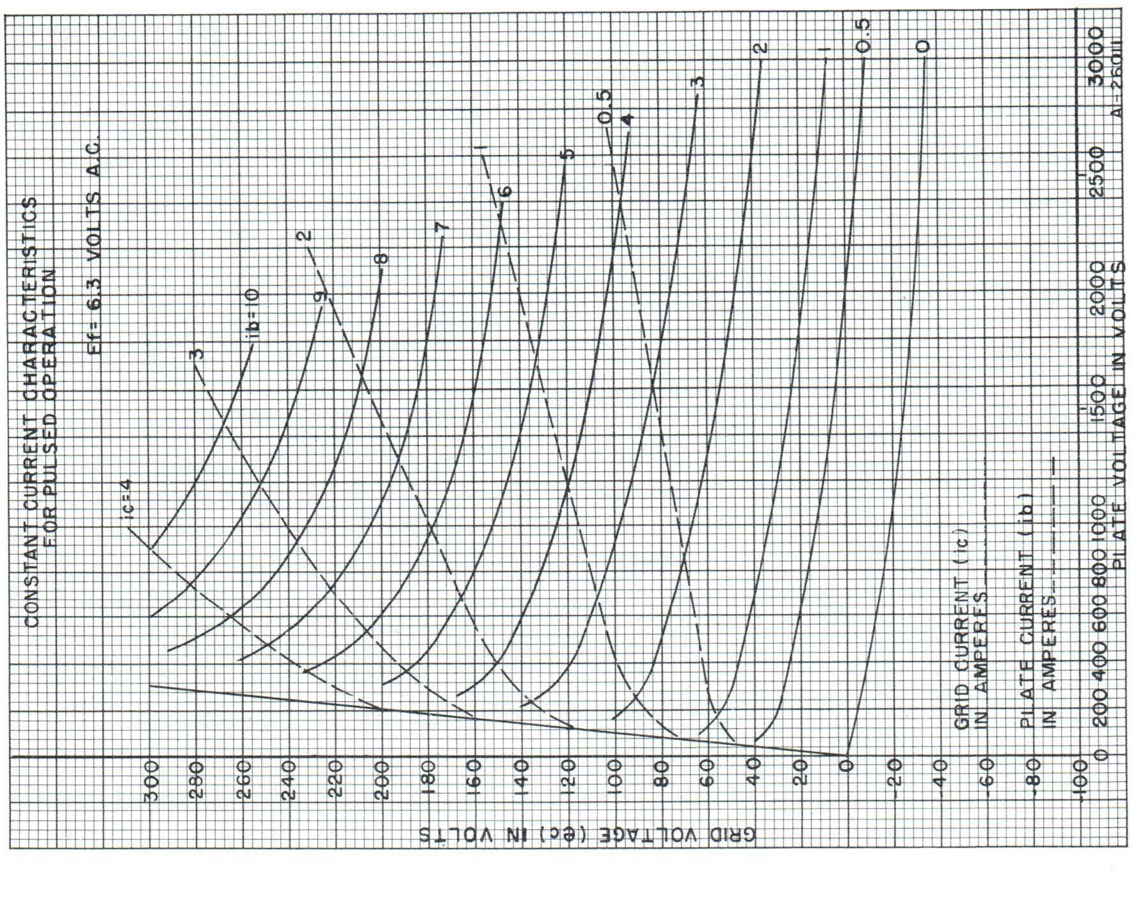
Note 3 — Capacitance measurements are with the tube cold.

Note 4 — With a plate-grid coaxial cavity of fixed dimensions, all tubes will resonate within the specified frequency range.


TYPICAL CONSTANT GRID VOLTAGE CHARACTERISTICS
Ef=6.3 VOLTS AC
Ec=GRID VOLTAGE IN VOLTS
PLATE CURRENT (Ib)
GRID CURRENT (Ic)
CURRENT IN MILLIAMPERES
PLATE VOLTAGE IN VOLTS


CONSTANT CURRENT CHARACTERISTICS
Ef=6.3 VOLTS AC
PLATE CURRENT (Ib) IN MILLIAMPERES
GRID CURRENT (Ic) IN MILLIAMPERES
GRID VOLTAGE (Ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-2607


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.3 VOLTS AC
ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
ec=300
250
200
150
100
50
30
0
-20
PEAK CURRENT IN AMPERES
PLATE VOLTAGE IN VOLTS
A-26012


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.3 VOLTS A.C.
ib=10
ic=4
GRID CURRENT (ic)
IN AMPERES
PLATE CURRENT (ib)
IN AMPERES
GRID VOLTAGE (ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-26011

ML-7211

High cathode current capability.

DESCRIPTION

The **ML-7211** is a ruggedized, high-mu, planar triode of ceramic and metal construction designed specifically for use as an oscillator, frequency multiplier, or amplifier in radio transmitting service at frequencies up to 2500 Mc. The tube may be operated at higher frequencies with reduced ratings.

Features of this tube include low interelectrode capacitance, high transconductance, high cathode current capability and great mechanical strength. The cathode is an indirectly-heated oxide-coated disc. The anode is forced-air cooled. This tube is manufactured to exacting dimensional tolerances to insure mechanical uniformity. Improved reliability and a minimum variation in electrical characteristics are achieved through extensive and precise electrical testing. The **ML-7211** is capable of sustained, reliable operation at elevated temperatures.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.3	Volts†
Heater Current (AC or DC) at 6.3 Volts	1.3	Amp
Heater Heating Time, minimum	60	Seconds
Amplification Factor	80	
Transconductance (I_b = 100 mA, E_b = 600 v)	30,000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.25	μμf
Grid-Cathode	8.0	μμf
Plate-Cathode, maximum	0.06	μμf
Frequency for Maximum Ratings	2500	Mc

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Anode Temperature	250	°C
Net Weight	2.5	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

R-F Power Amplifier and Oscillator

Key-down conditions per tube without amplitude modulation‡

Maximum Ratings, Absolute Values

D-C Plate Voltage	1000	volts
D-C Grid Voltage	–150	volts
D-C Cathode Current▲	190	mA
D-C Grid Current§	45	mA
Peak Positive RF Grid-Cathode Voltage	30	volts
Peak Negative RF Grid-Cathode Voltage	–400	volts
Plate Dissipation† (Forced-air Cooling)	100	watts
Grid Dissipation	2	watts

Typical Operation

Power Amplifier, Grid Separation Circuit — 500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage	–30	volts
D-C Plate Current	140	mA
D-C Grid Current, Approximate	40	mA
Driving Power, Approximate	9	watts
Useful Power Output	65	watts

RF Oscillator — 2500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage, Approximate	–20	volts
D-C Plate Current	140	mA
D-C Grid Current	15	mA
Useful Power Output	25	watts

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

▲See "Maximum Cathode Current Rating"

§See "Application Notes" on "Determination of Proper Grid Drive".

†Refer to "Cooling" under "Application Notes".

Characteristic Range Values for Equipment Design

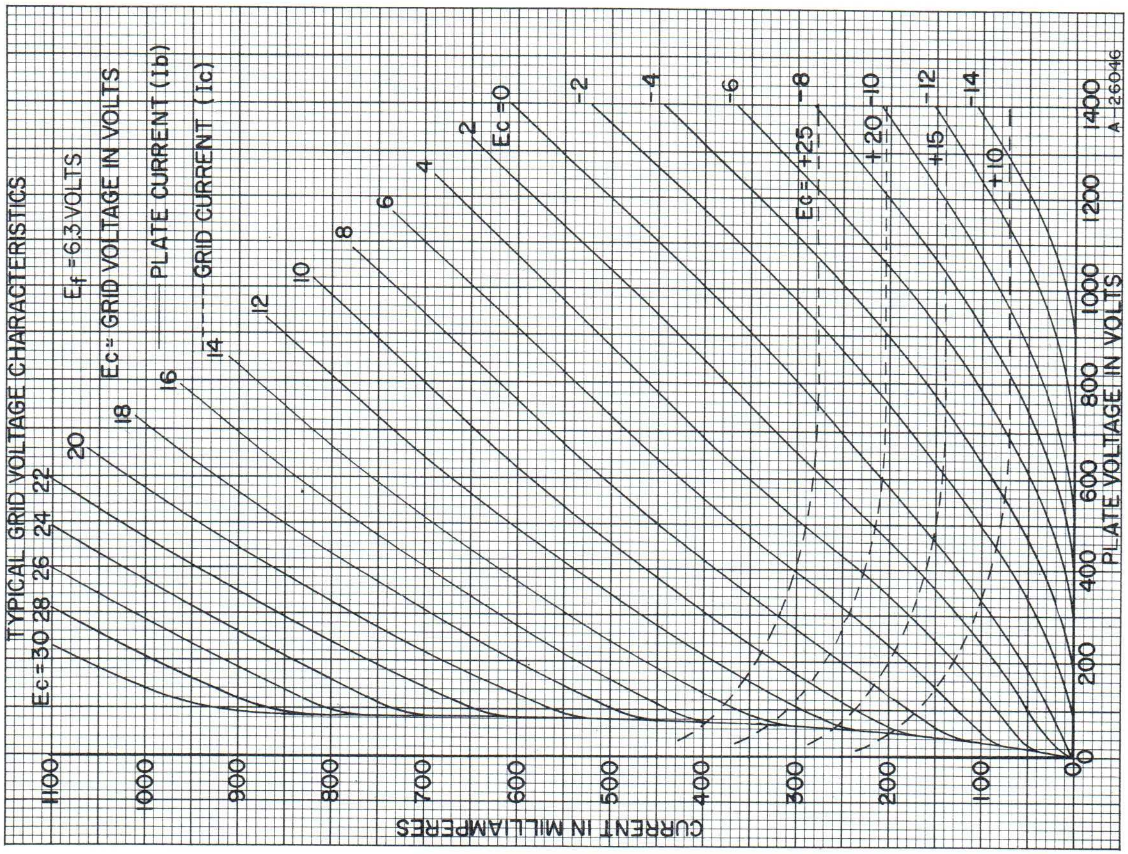
	Min.	Max.	
Filament Current at 6.3 volts	1.20	1.40	A
Cut-off bias (Note 1)	—	–20	volts
Grid-Plate Capacitance (Note 2)	2.10	2.40	$\mu\mu f$
Grid-Cathode Capacitance (Note 2)	7.0	9.0	$\mu\mu f$

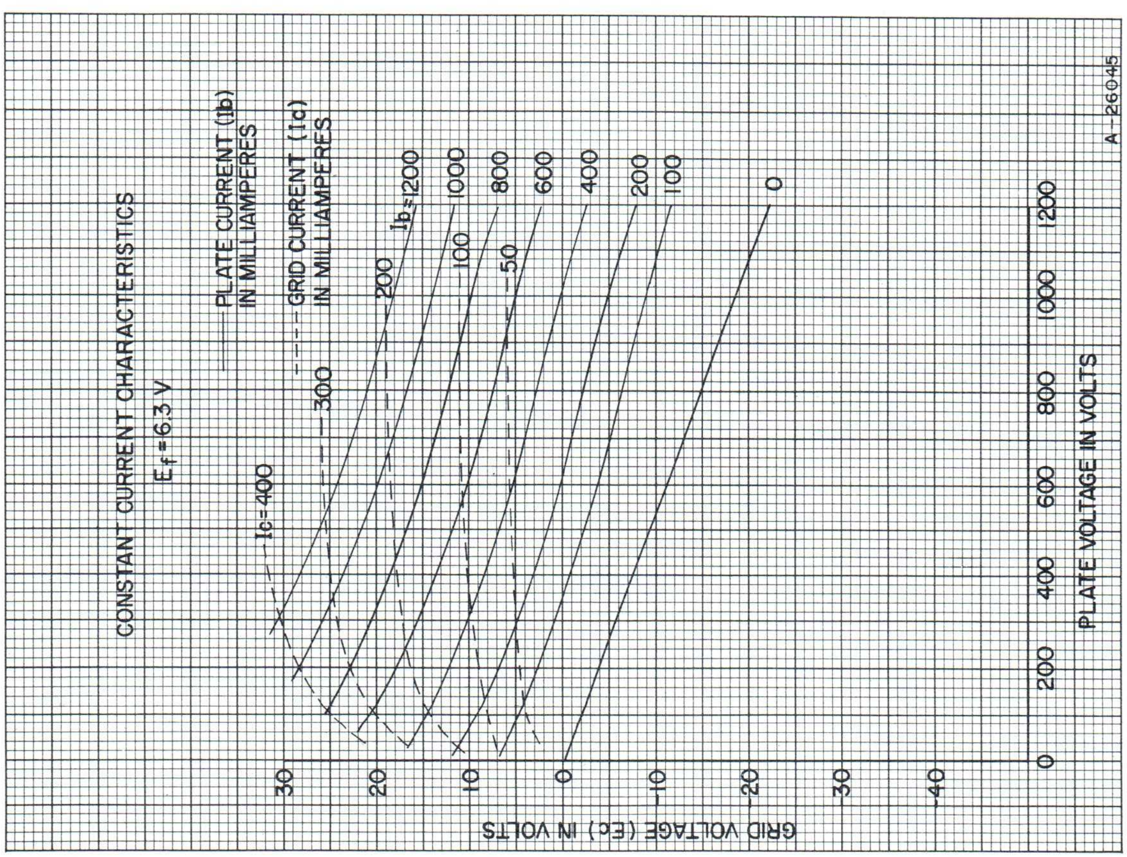
Note 1 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

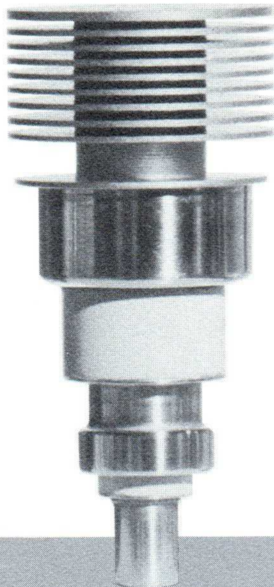
Note 2 — Capacitance measurements are with the tube cold.

Maximum Cathode Current Rating

The rating of the ML-7211 for maximum d-c cathode current exceeds that of other tubes which will fit the same socket. The increased rating is made possible by an increase in the emission capability of the cathode. Note that while increased power output is obtainable from this tube, the plate efficiency is only slightly increased; the principle portion of the increase in power output will be due to an increase in power input.


TYPICAL GRID VOLTAGE CHARACTERISTICS
Ef = 6.3 VOLTS
Ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (Ib)
GRID CURRENT (Ic)
CURRENT IN MILLIAMPERES
PLATE VOLTAGE IN VOLTS
A-26046


CONSTANT CURRENT CHARACTERISTICS
Ef = 6.3 V
PLATE CURRENT (Ib) IN MILLIAMPERES
GRID CURRENT (Ic) IN MILLIAMPERES
GRID VOLTAGE (Ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-26045



ML-7289 / 3CX100A5

General purpose application.

DESCRIPTION

The **ML-7289/3CX100A5** is a ruggedized, high-mu, planar triode of ceramic and metal construction designed specifically for use in new equipment as an oscillator, amplifier or frequency multiplier, at frequencies up to 2500 Mc. It is well suited for pulsed operation at frequencies up to 3000 Mc.

The **ML-7289/3CX100A5** can, in most cases, replace the 3CX100A5, 2C39A or 2C39WA directly without equipment modification. It retains the desirable high-mu, low interelectrode capacitance and high transconductance characteristics of its predecessors. It is manufactured to exacting dimensional tolerances to insure mechanical uniformity. Improved reliability and minimum variation in electrical characteristics are achieved through extensive and precise electrical testing. The **ML-7289/3CX100A5** is capable of sustained, reliable operation at elevated temperatures.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.0	Volts†
Heater Current (AC or DC) at 6.0 Volts	1.0	Amp
Heater Heating Time, minimum	60	secs
Amplification Factor	100	
Transconductance (I_b = 70 mA, E_b = 600 v)	25,000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.0	μμf
Grid-Cathode	6.30	μμf
Plate-Cathode, maximum	0.035	μμf
Duty Cycle	0.0025	
Maximum Pulse Length	3	μsec

Mechanical

Mounting Position	Optional	
Type of Cooling	Forced Air*	
Maximum Anode Shank and Envelope Temperature	300	°C
Altitude Rating, CW operation	60000	feet
Net Weight	2.5	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

R-F Power Amplifier and Oscillator

Key-down conditions per tube without amplitude modulation‡

Maximum Ratings, Absolute Values

D-C Plate Voltage	1000	volts
D-C Grid Voltage▲	-150	volts
D-C Cathode Current	125	mA
D-C Grid Current§	50	mA
Plate Dissipation† (Forced-Air Cooling)	100	watts
Grid Dissipation	2	watts
Frequency	2500	Mc

Typical Operation

Power Amplifier, Grid Separation Circuit — 500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage	-40	volts
D-C Plate Current	90	mA
D-C Grid Current, Approximate	30	mA
Driving Power, Approximate	6	watts
Useful Power Output	40	watts

R-F Oscillator — 2500 Mc

D-C Plate Voltage	900	volts
D-C Grid Voltage, Approximate	-22	volts
D-C Plate Current	90	mA
D-C Grid Current	10	mA
Useful Power Output	17	watts

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*	600	volts
D-C Grid Voltage▲	-150	volts
D-C Cathode Current	100	mA
D-C Grid Current§	50	mA
Plate Dissipation† (Forced-Air Cooling)	70	watts
Grid Dissipation	2	watts
Frequency	2500	Mc

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

▲The maximum instantaneous peak grid-cathode voltages for CW ratings should be within the range of +30 to −400 volts.

§See "Application Notes" on "Determination of Proper Grid Drive".

†Refer to "Cooling" under "Application Notes".

*For modulation factors less than 1.0, a higher d-c plate voltage may be used if the sum of the peak audio voltage and the d-c plate voltage does not exceed 1200 volts.

Plate-Pulsed Oscillator and Amplifier Class C

Maximum Ratings, Absolute Values

For a pulse length of	3	μsec
Duty Factor	0.0025	
Peak Plate Pulse Supply Voltage	3500	volts
Grid Bias Voltage□	-150	volts
Peak Plate Current from Pulse Supply	3	amps
Peak Grid Current	1.8	amps
Average Plate Dissipation† (Forced-Air Cooling)	27	watts
Average Grid Dissipation	2	watts
Frequency	3000	Mc

Typical Operation: 3000 Mc Oscillator

Pulse Length	3	μsec
Duty Factor	0.0025	
Filament Voltage	5.8	volts
Peak Plate Pulse Supply Voltage	3500	volts
Peak Plate Current from Pulse Supply	3	amps
Peak Grid Current	1.8	amps
Useful Peak Power Output, Approximate	1600	watts

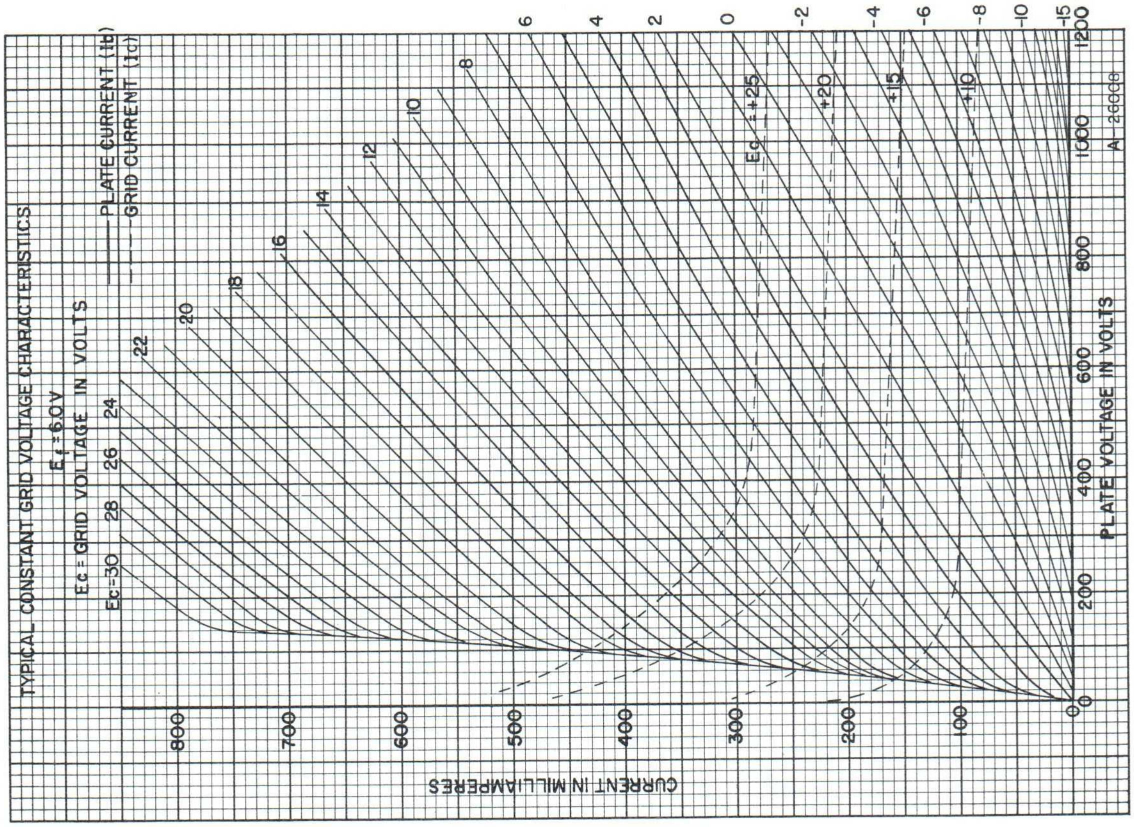
□The maximum instantaneous peak grid-cathode voltages for pulsed ratings should be within the range of +250 to −750 volts.

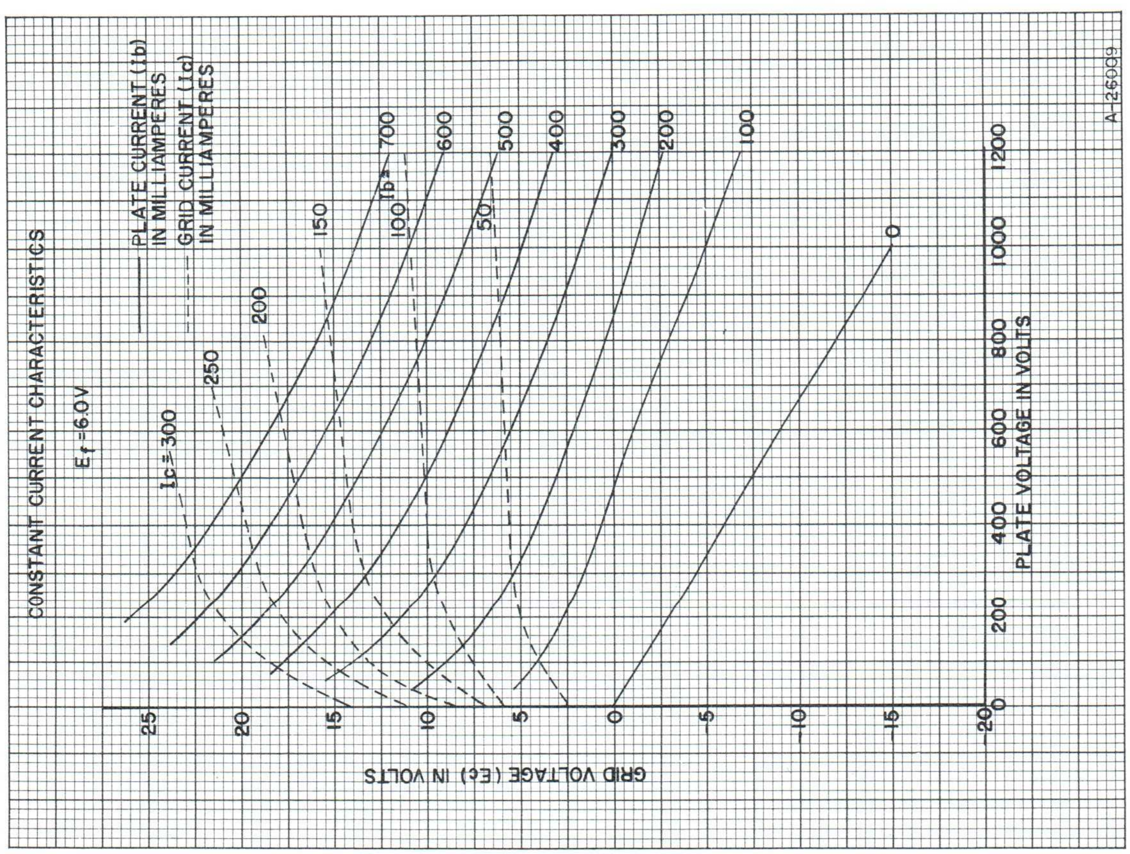
Characteristic Range Values for Equipment Design

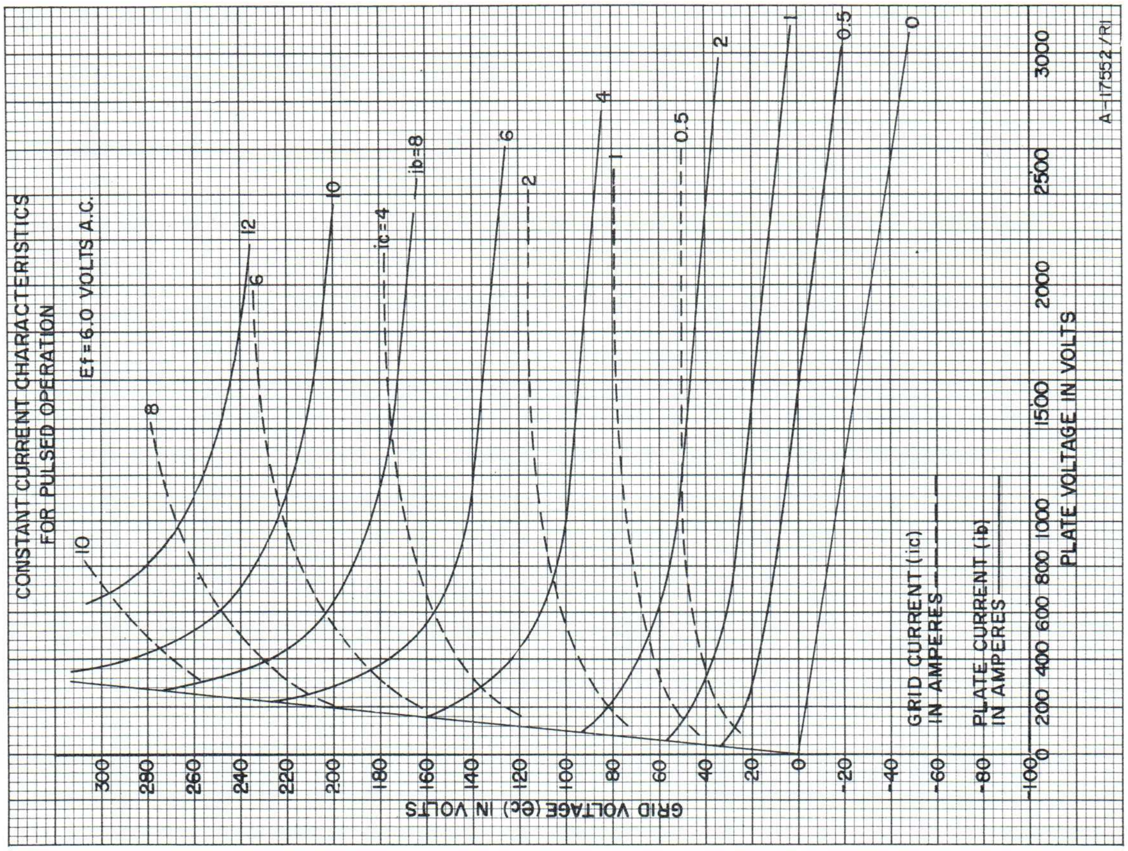
	Min.	Max.	
Filament Current at 6.0 volts	0.90	1.05	A
Cut-off bias (Note 1)	—	-15	volts
Grid-Plate Capacitance (Note 2)	1.95	2.15	μμf
Grid-Cathode Capacitance (Note 2)	5.60	7.00	μμf

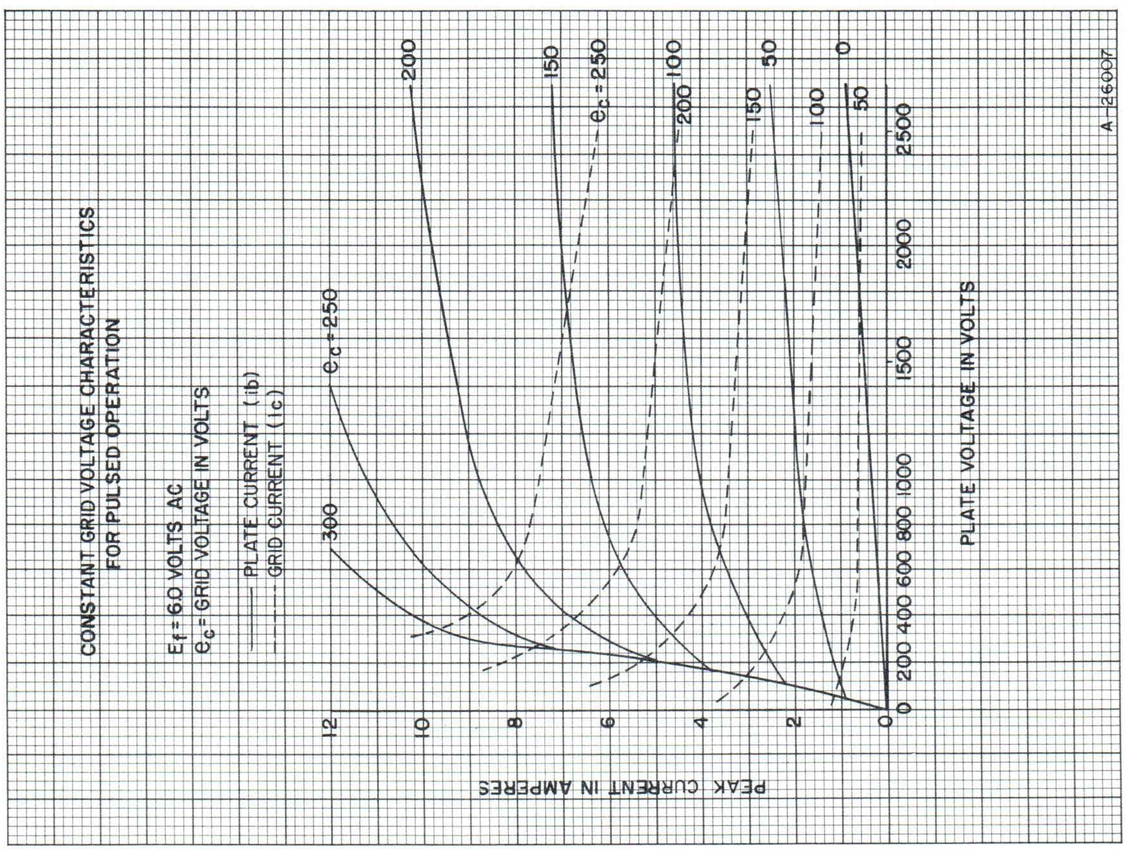
Note 1 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

Note 2 — Capacitance measurements are with the tube cold.


TYPICAL CONSTANT GRID VOLTAGE CHARACTERISTICS
Ef = 6.0V
Ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (Ib)
GRID CURRENT (Ic)
CURRENT IN MILLIAMPERES
PLATE VOLTAGE IN VOLTS
A-26008


CONSTANT CURRENT CHARACTERISTICS
Ef = 6.0V
PLATE CURRENT (Ib) IN MILLIAMPERES
GRID CURRENT (Ic) IN MILLIAMPERES
GRID VOLTAGE (Ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
A-26009


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS A.C.
GRID CURRENT (ic)
IN AMPERES
PLATE CURRENT (ib)
IN AMPERES
PLATE VOLTAGE IN VOLTS
GRID VOLTAGE (ec) IN VOLTS
A-17552/R1


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS AC
ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
PEAK CURRENT IN AMPERES
PLATE VOLTAGE IN VOLTS
A-26007

ML-7698

High cathode current capability. Plate- or Grid-pulsed application.

DESCRIPTION

The **ML-7698** is a high-mu planar triode designed for use as a grid-pulsed or plate-pulsed oscillator, frequency multiplier or power amplifier in radio transmitting service from low-frequency to 3000 Mc. Special features of this tube as compared to similar tube types include high current carrying capability, high duty-factor and pulse-length ratings, and a cathode design permitting grid-pulsed operation with up to 2000 Vdc plate voltage. This tube has an extended grid-anode insulator, which is an important feature in airborne equipment operating at very high altitude. Other features include low interelectrode capacitance, high transconductance, great mechanical strength, and capability for sustained, reliable operation at elevated temperatures.

Compact metal-and-ceramic coaxial construction makes the tubes well suited for operation in line-type circuits at lower frequencies as well as in cavity resonators at the higher frequencies. The cathode is an indirectly heated disc with an oxide coating impregnated in a nickel matrix. The unique matrix construction (in combination with proper plate series impedance) reduces to a minimum failures of the cathode due to voltage surges thereby further increasing the reliability of this tube. The anode of the **ML-7698** is cooled by conduction and convection.

This tube is manufactured to exacting dimensional tolerances to insure mechanical uniformity. Improved reliability and a minimum variation in electrical characteristics are achieved through extensive and precise electrical testing.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.3	Volts†
Heater Current (AC or DC) at 6.3 volts	1.3	Amps
Heater Heating Time, minimum	60	sec
Amplification Factor	80	
Transconductance (I_b = 100 mA, E_b = 600 v)	30000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.25	μμf
Grid-Cathode	8.0	μμf
Plate-Cathode, maximum	0.06	μμf

Mechanical

Mounting Position	Optional	
Type of Cooling	Conduction and Convection*	
Maximum Anode Temperature	250	°C
Net Weight	1.8	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Plate-Pulsed Oscillator and Amplifier—Class C

Maximum Ratings, Absolute Values		
Pulse Length†	6	μsec.
Duty Factor†	0.0033	
Peak Plate Pulse Supply Voltage	3500	volts
D-C Grid Bias Voltage‡	−150	volts
Peak Plate Current from Pulse Supply△	5.0	amps
Average Plate Current△	13	mA
Average Grid Current	6	mA
Average Plate Dissipation§	10	watts
Average Grid Dissipation	2	watts
Frequency	3000	Mc
Typical Operation — Oscillator		
Pulse Length	3	μsec
Duty Factor	0.0025	
Filament Voltage	5.8	volts
Peak Plate Pulse Supply Voltage	3500	volts
Peak Plate Current from Pulse Supply	4.8	amps
Average Plate Current	12	mA
Average Grid Current	4	mA
Useful Peak Power Output, approximate	2500	watts
Frequency	3000	Mc

Grid-Pulsed Oscillator and Amplifier—Class C

Maximum Ratings, Absolute Values		
Pulse Length†	6	μsec
Duty Factor†	.0033	
D-C Plate Voltage	2000	volts
D-C Grid Bias Voltage‡	−150	volts
Peak Plate Current from D-C Supply△	5.0	amps.
Average Plate Current△	13	mA
Average Grid Current	6	mA
Average Plate Dissipation§	10	watts
Average Grid Dissipation	2	watts
Frequency	3000	Mc

Typical Operation — Amplifier		
Pulse Length†	3.5	μsec
Duty Factor†	0.001	
Filament Voltage	6.3	volts
D-C Plate Voltage	2000	volts
D-C Grid Bias Voltage	−70	volts
Peak Plate Current from D-C Supply	3.0	amps
Peak Grid Current from Pulse Supply	1.0	amp
Driving Power during Pulse, approximate	400	watts
Useful Peak Power Output, approximate	2500	watts
Frequency	1100	Mc

†For applications requiring longer pulse lengths or higher duty factors, consult the Machlett Engineering Department.

‡The maximum instantaneous peak grid-cathode voltage should be within the range of +250 to −750 volts.

△See "Maximum Plate Current Ratings" under "Application Notes".

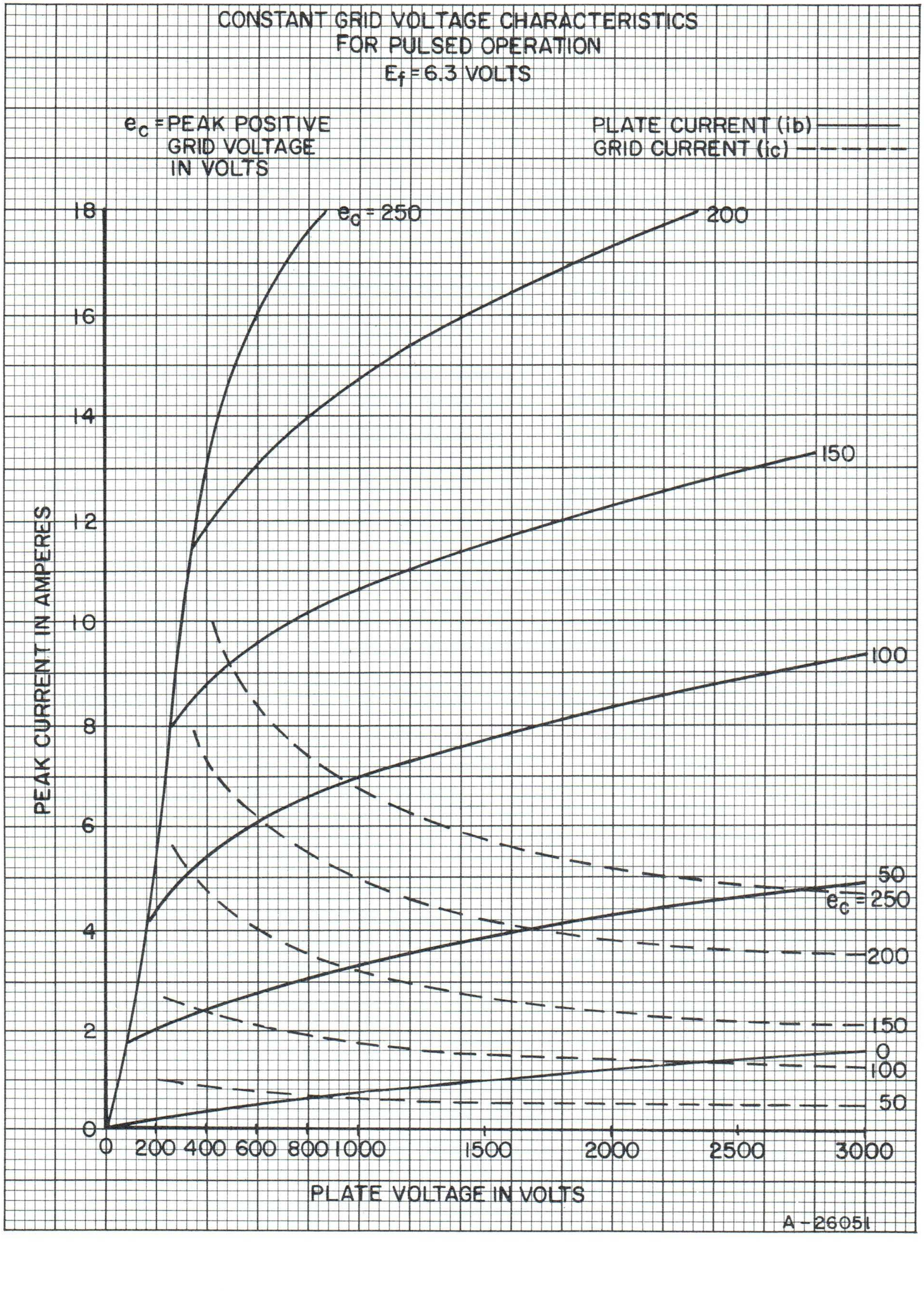
§For higher plate dissipation ratings refer to "Cooling" under "Application Notes".

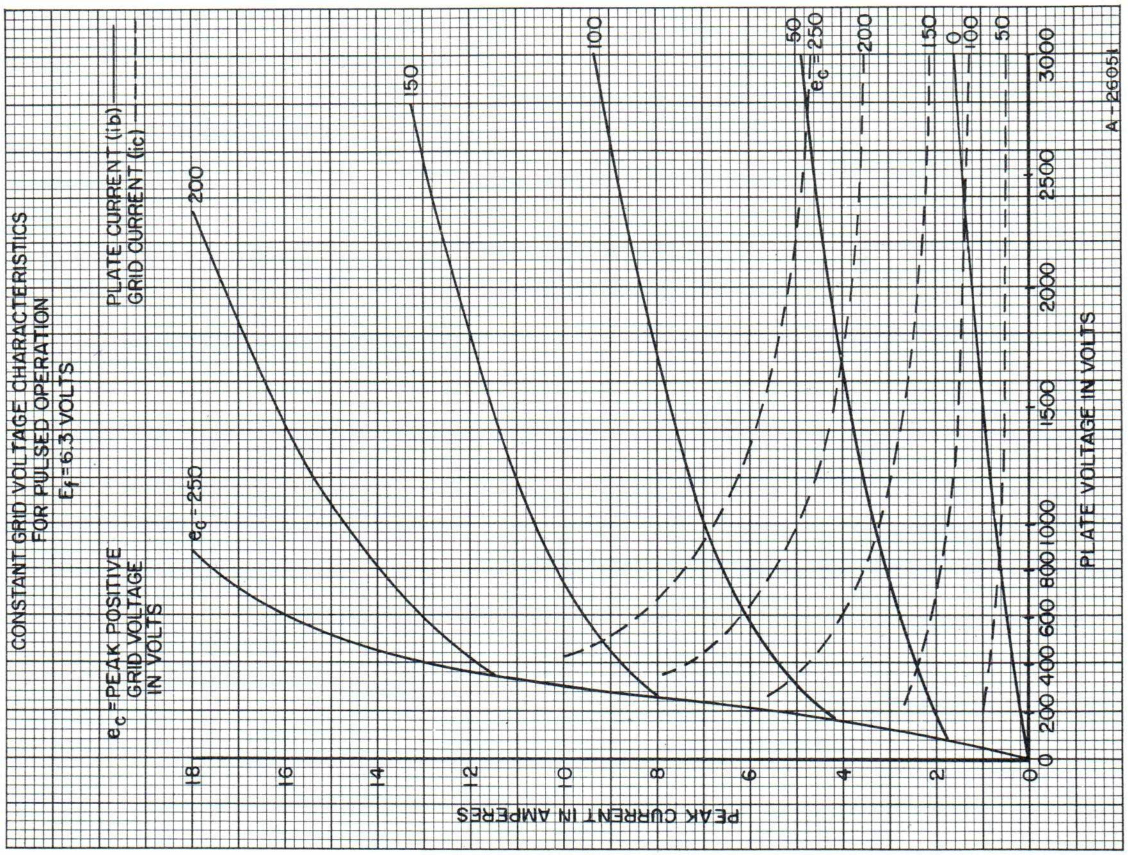
Characteristic Range Values for Equipment Design

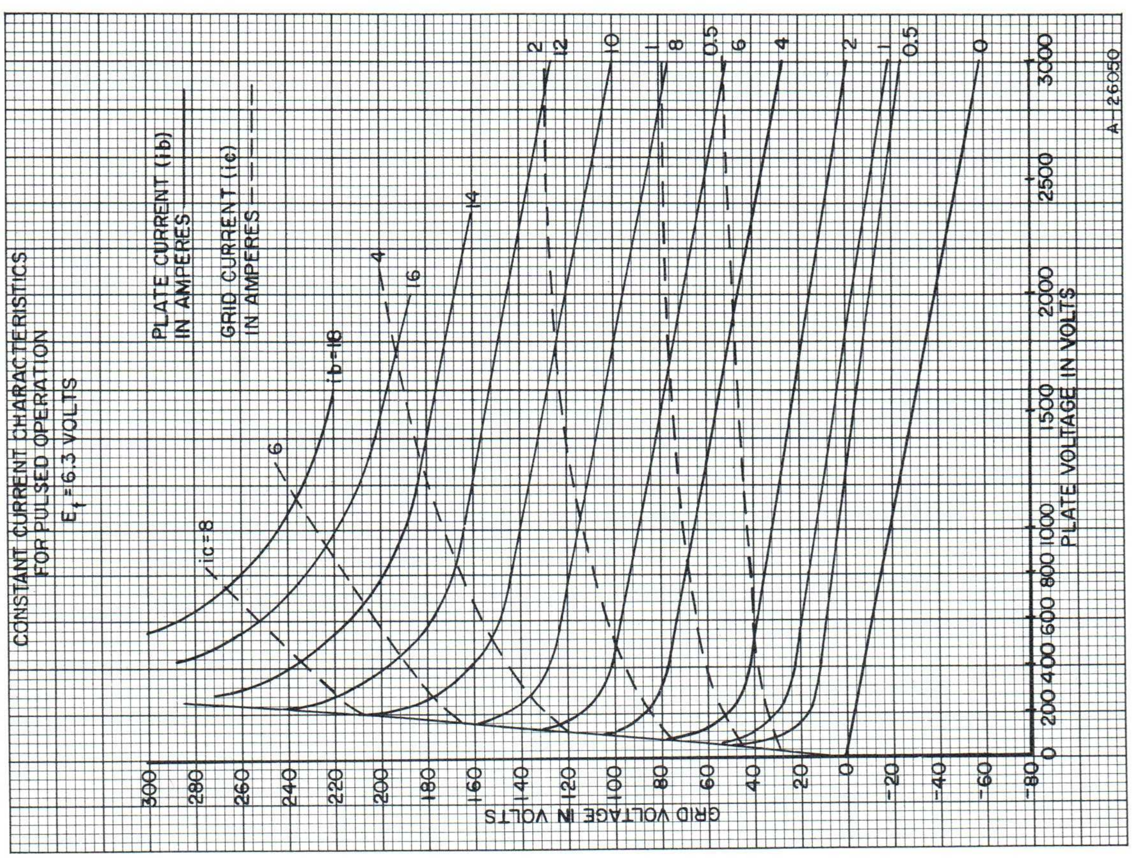
	Min.	Max.	
Filament Current at 6.3 Volts	1.20	1.40	A
Cutoff Bias (Note 1)	—	−20	V
Grid-Plate Capacitance (Note 2)	2.10	2.40	μμf
Grid-Cathode Capacitance (Note 2)	7.0	9.0	μμf

Note 1 — Measured at 1 mA of plate current and a plate voltage of 600 volts.

Note 2 — Capacitance measurements are made with tube cold.


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.3 VOLTS
ec = PEAK POSITIVE GRID VOLTAGE IN VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
ec = 250
200
150
100
50
ec = 250
200
150
0
100
50
PEAK CURRENT IN AMPERES
0
2
4
6
8
10
12
14
16
18
0
200
400
600
800
1000
1500
2000
2500
3000
PLATE VOLTAGE IN VOLTS
A-26051


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
E_f=6.3 VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
e_c = PEAK POSITIVE GRID VOLTAGE IN VOLTS
PEAK CURRENT IN AMPERES
PLATE VOLTAGE IN VOLTS
A-26051


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
E_f=6.3 VOLTS
PLATE CURRENT (ib) IN AMPERES
GRID CURRENT (ic) IN AMPERES
GRID VOLTAGE IN VOLTS
PLATE VOLTAGE IN VOLTS
A-26050

ML-7815 / 3CPN10A5

Plate- or Grid-pulsed application.

DESCRIPTION

The **ML-7815/3CPN10A5** is a high-mu planar triode designed for use as a grid-pulsed or plate-pulsed oscillator, frequency multiplier or power amplifier in radio transmitting service from low-frequency to 3000 Mc. Special features of this tube as compared to similar tube types include high duty-factor and pulse-length ratings and a cathode design permitting grid-pulsed operation with up to 2000 Vdc plate voltage. This tube has an extended grid-anode insulator which is an important feature in airborne equipment operating at very high altitude. Other features include low interelectrode capacitance, high transconductance, great mechanical strength, and capability for sustained, reliable operation at elevated temperatures.

Compact metal-and-ceramic coaxial construction makes the tubes well suited for operation in line-type circuits at lower frequencies as well as in cavity resonators at the higher frequencies. The cathode is an indirectly heated disc with an oxide coating impregnated in a nickel matrix. The unique matrix construction (in combination with proper plate series impedance) reduces to a minimum failures of the cathode due to voltage surges thereby further increasing the reliability of this tube. The anode of the **ML-7815/3CPN10A5** is cooled by conduction and convection.

GENERAL CHARACTERISTICS

Electrical

Heater Voltage	6.0	Volts†
Heater Current (AC or DC) at 6.0 volts	1.0	Amp
Heater Heating Time, minimum	60	sec
Amplification Factor	100	
Transconductance (I_b=70 mA E_b=600 v)	25000	μmhos
Interelectrode Capacitances (without heater voltage)		
Grid-Plate	2.05	μμf
Grid-Cathode	6.30	μμf
Plate-Cathode, maximum	0.035	μμf

Mechanical

Mounting Position	Optional	
Type of Cooling	Conduction and Convection*	
Maximum Anode Temperature	250	°C
Net Weight	1.7	oz.

†See Application Note, page 16, for optimum heater voltage.

*See Application Notes, page 16 and also air cooling curves, page 83.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Plate-Pulsed Oscillator and Amplifier—Class C

Maximum Ratings, Absolute Values

Pulse Length†	6	μsec
Duty Factor†	0.0033	
Peak Plate Pulse Supply Voltage	3500	volts
D-C Grid Bias Voltage‡	−150	volts
Peak Plate Current from Pulse Supply	3.0	amps
Average Plate Current	10	mA
Average Grid Current	5	mA
Average Plate Dissipation§	10	watts
Average Grid Dissipation	2	watts
Frequency	3000	Mc

Typical Operation — Oscillator

Pulse Length	5	μsec
Duty Factor	0.0030	
Filament Voltage	5.8	volts
Peak Plate Pulse Supply Voltage	3500	volts
Peak Plate Current from Pulse Supply	3.0	amps
Average Plate Current	9	mA
Average Grid Current	3	mA
Useful Peak Power Output, approximate	2000	watts
Frequency	2500	Mc

Characteristic Range Values for Equipment Design

	Min.	Max	
Filament Current at 6.0 Volts	0.90	1.05	A
Cutoff Bias (Note 1)	—	−15	V
Grid-Plate Capacitance (Note 2)	1.95	2.15	μμf
Grid-Cathode Capacitance (Note 2)	5.60	7.00	μμf
Plate-Cathode Capacitance (Note 2)	—	0.035	μμf

Note 1—Measured at 1 mA of plate current and a plate voltage of 600 volts.

Note 2—Capacitance measurements are made with tube cold.

Grid-Pulsed Oscillator and Amplifier—Class C

Maximum Ratings, Absolute Values

Pulse Length†	6	μsec
Duty Factor†	.0033	
D-C Plate Voltage	2000	volts
D-C Grid Bias Voltage‡	−150	volts
Peak Plate Current from D-C Supply	3.0	amps
Average Plate Current	10	mA
Average Grid Current	5	mA
Average Plate Dissipation§	10	watts
Average Grid Dissipation	2	watts
Frequency	3000	Mc

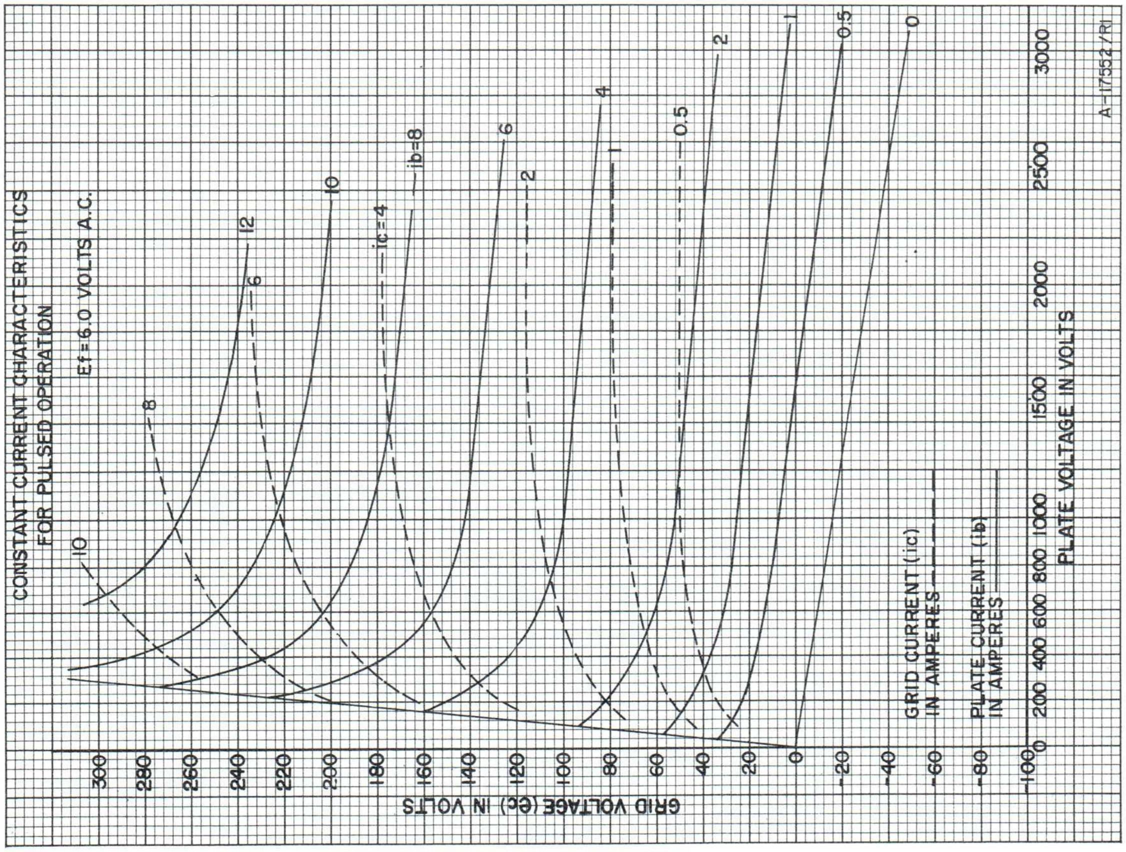
Typical Operation — Amplifier

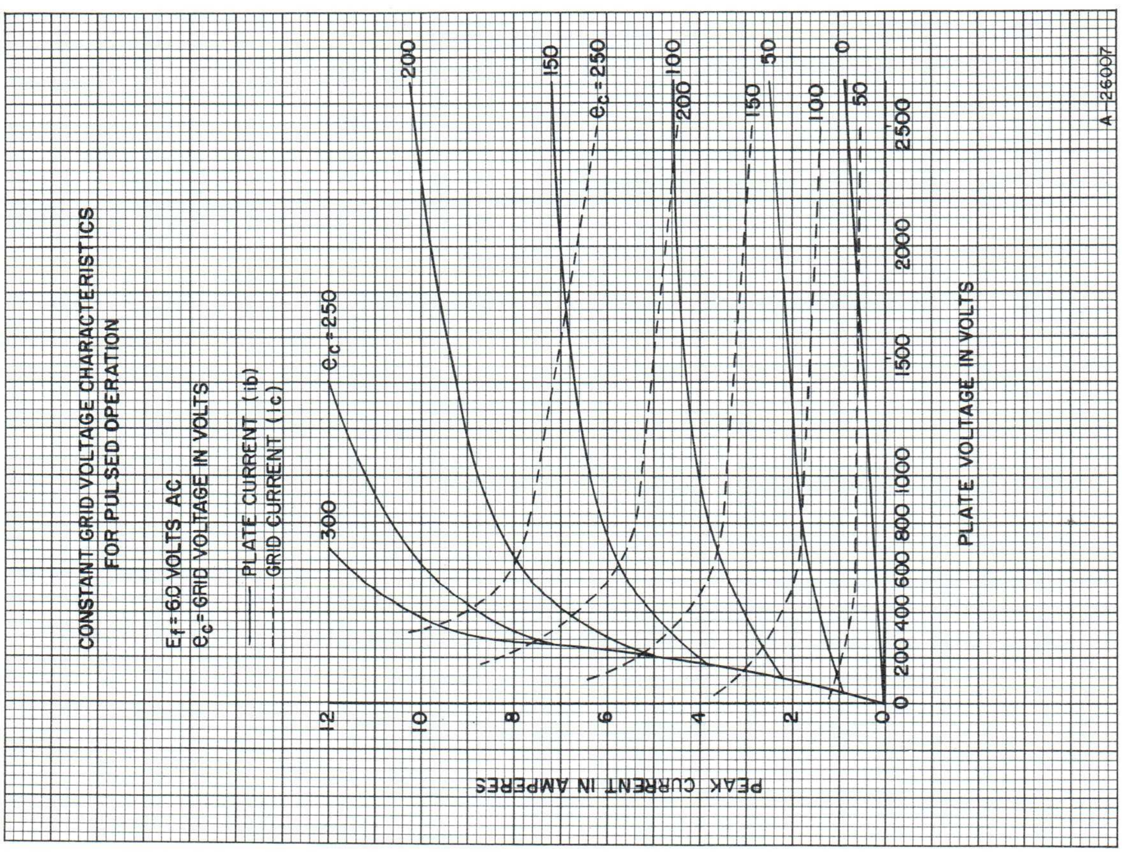
Pulse Length	3.5	μsec
Duty Factor	0.001	
Filament Voltage	6.0	volts
D-C Plate Voltage	1700	volts
D-C Grid Bias Voltage	−45	volts
Peak Plate Current from D-C Supply	1.9	amps
Peak Grid Current from Pulse Supply	1.1	amps
Driving Power during Pulse, approximate	400	watts
Useful Peak Power Output, approximate	1500	watts
Frequency	1100	Mc

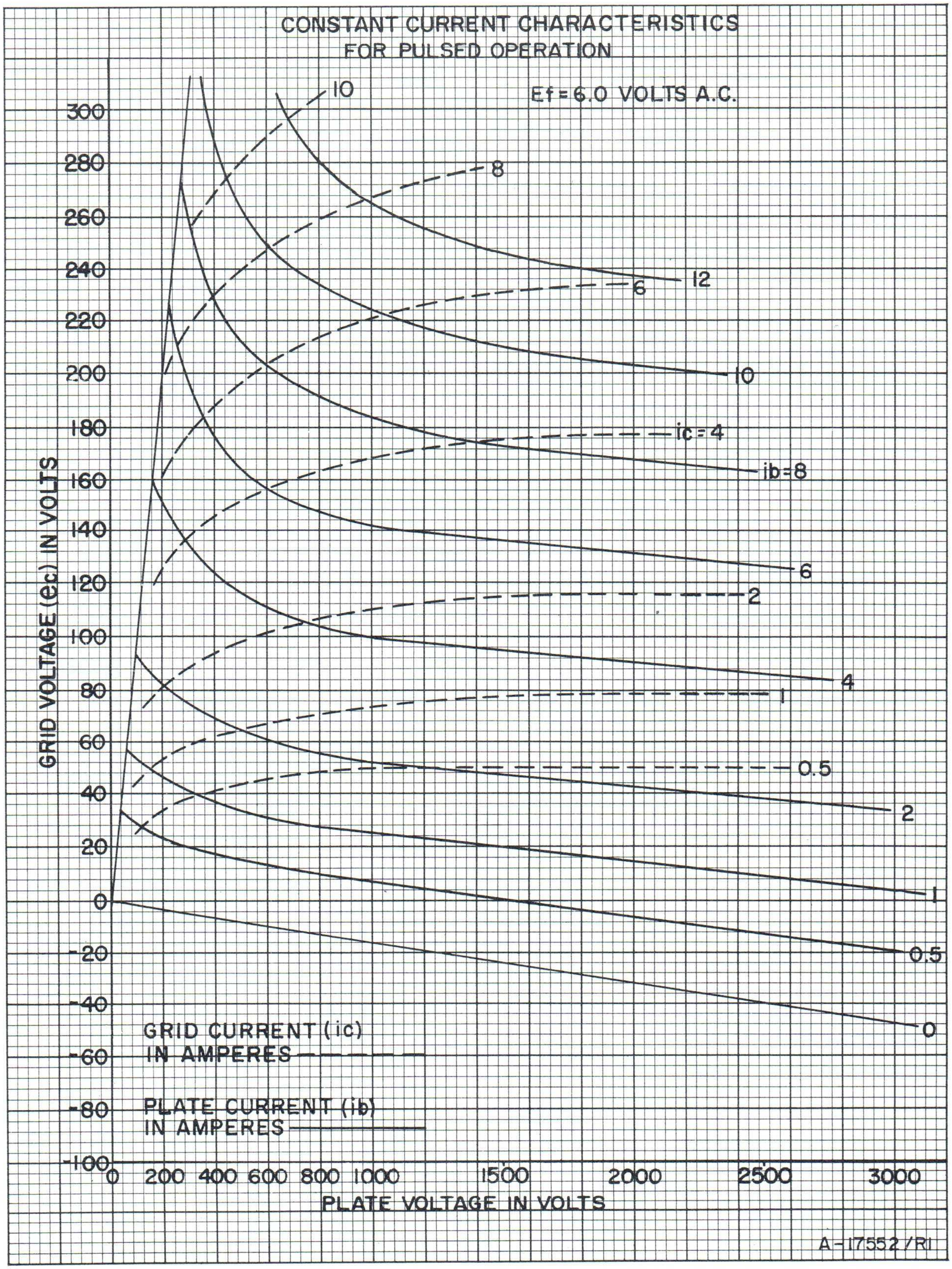
†For applications requiring longer pulse lengths or higher duty factors, consult the Machlett Engineering Department.

‡The maximum instantaneous peak grid-cathode voltage should be within the range of +250 to −750 volts.

§For higher plate dissipation ratings refer to "Cooling" under "Application Notes".


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
Ef=6.0 VOLTS A.C.
GRID CURRENT (ic)
IN AMPERES
PLATE CURRENT (ib)
IN AMPERES
PLATE VOLTAGE IN VOLTS
GRID VOLTAGE (ec) IN VOLTS
A-17552/R1


CONSTANT GRID VOLTAGE CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS AC
ec = GRID VOLTAGE IN VOLTS
PLATE CURRENT (ib)
GRID CURRENT (ic)
PLATE VOLTAGE IN VOLTS
PEAK CURRENT IN AMPERES
A-26007


CONSTANT CURRENT CHARACTERISTICS
FOR PULSED OPERATION
Ef = 6.0 VOLTS A.C.
GRID VOLTAGE (ec) IN VOLTS
PLATE VOLTAGE IN VOLTS
GRID CURRENT (ic) IN AMPERES
PLATE CURRENT (ib) IN AMPERES
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
200
400
600
800
1000
1500
2000
2500
3000
10
8
6
ic = 4
2
1
0.5
12
10
ib = 8
6
4
2
1
0.5
0
A-17552/R1

ML-7855

Frequency stable operation within 2 seconds*.

DESCRIPTION

The **ML-7855** is a ruggedized, high-mu planar triode of ceramic and metal construction, designed for use as an oscillator, frequency multiplier, or amplifier in radio transmitting service at frequencies up to 2500 Mc. The tube may be operated at higher frequencies with reduced ratings.

In addition to low interelectrode capacitance, high transconductance and high-mu, this tube incorporates design features which help to assure frequency stable operation even under adverse ambient temperature and varying plate dissipation conditions. The cathode is an indirectly heated oxide-coated disc. The anode is forced-air cooled. Anode adaptors for heatsink cooling can be provided upon request.

TENTATIVE

GENERAL CHARACTERISTICS

Electrical		
Heater Voltage	6.0	Volts †
Heater Current (AC or DC) at 6.0 Volts	1.0	Amp
Cathode Heating Time, minimum	60	secs
Amplification Factor	80	
Transconductance (I_b=70 mA, E_b=600 V)	25,000	μmhos
Interelectrode Capacitances (without heater voltage):		
Grid-Plate	2.5	μμf
Grid-Cathode	6.60	μμf
Plate-Cathode, maximum	.06	μμf
Frequency for Maximum Ratings	2500	Mc
Mechanical		
Mounting Position	Optional	
Type of Cooling	Forced-Air ‡	
Maximum Anode Temperature	250	°C
Net Weight, approximate	2.5	oz.

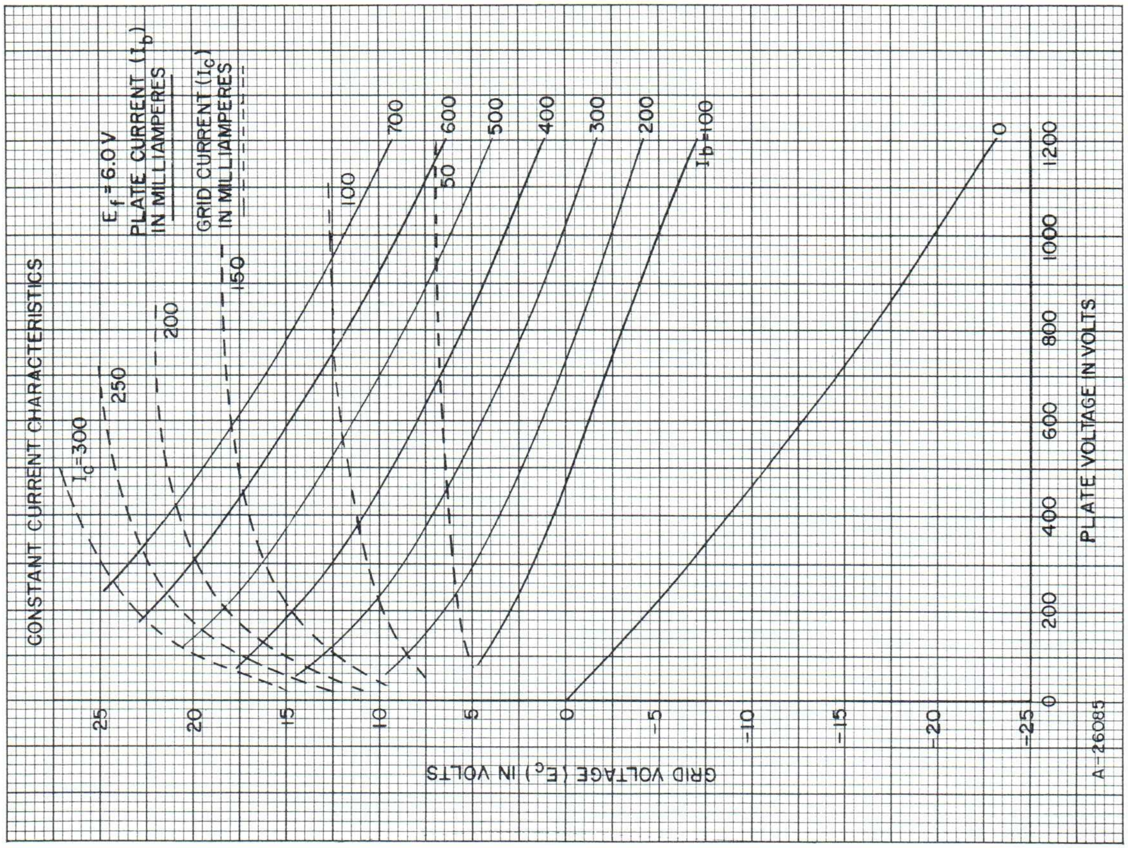
MAXIMUM RATINGS RF Power Amplifier and Oscillator

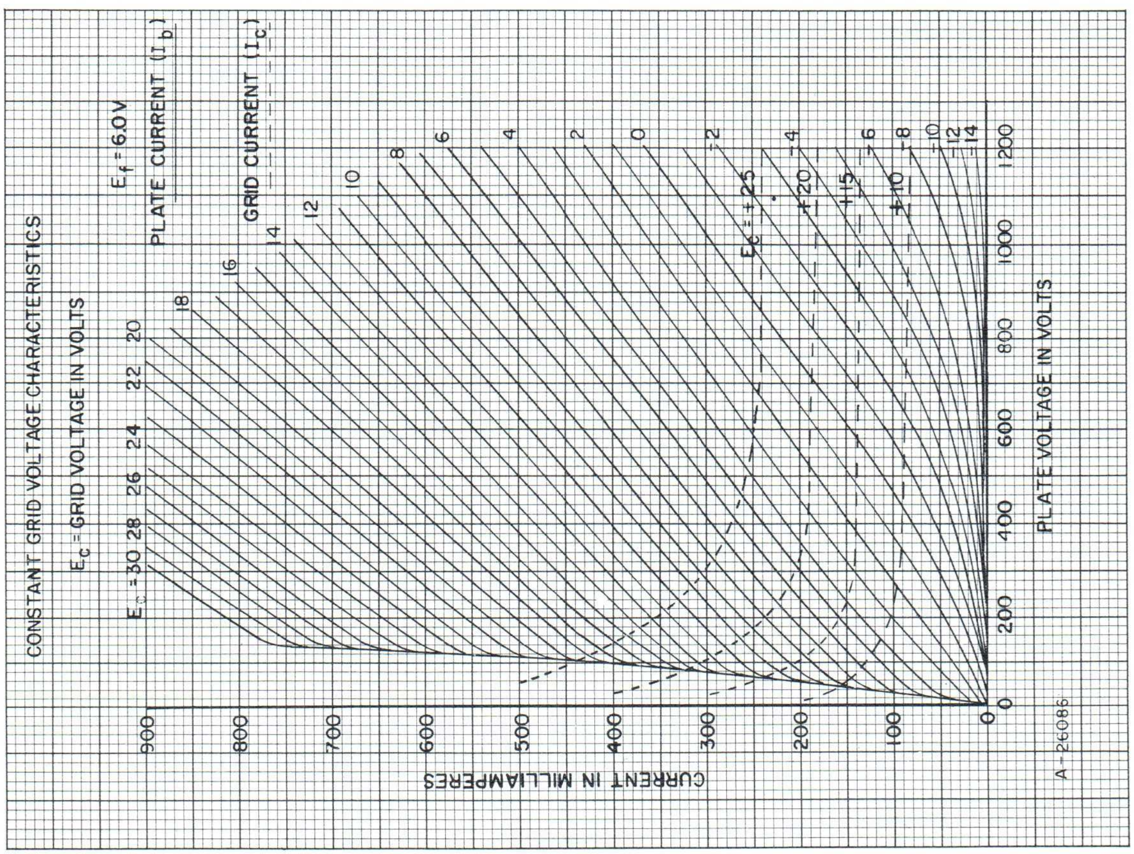
Maximum Ratings, Absolute Values		
DC Plate Voltage	1000	Volts
DC Grid Voltage	−150	Volts
DC Cathode Current	125	mA
DC Grid Current	30	mA
Peak Positive RF Grid-Cathode Voltage	30	volts
Peak Negative RF Grid-Cathode Voltage	−400	volts
Plate Dissipation (Forced-air cooling or with appropriate heatsink)	100	Watts
Grid Dissipation	2	Watts

†See Application Note, page 16, for optimum heater voltage.

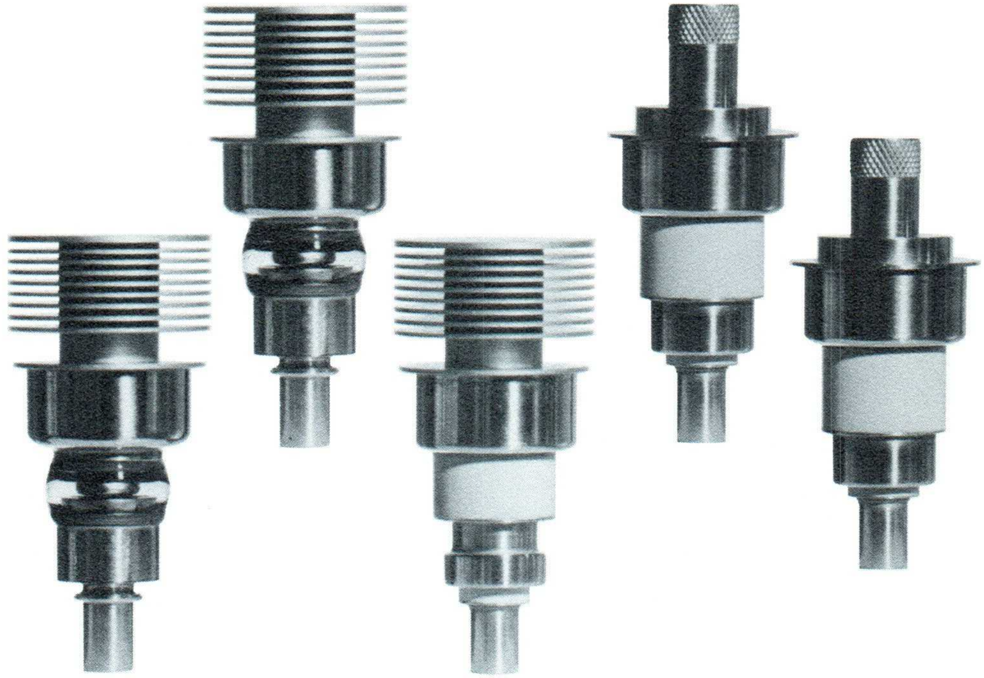
* Or longer, depending on circuitry.

‡See Application Notes, page 16 and also air cooling curves, page 83.


CONSTANT CURRENT CHARACTERISTICS
E_f = 6.0 V
PLATE CURRENT (I_b) IN MILLIAMPERES
GRID CURRENT (I_c) IN MILLIAMPERES
PLATE VOLTAGE IN VOLTS
GRID VOLTAGE (E_c) IN VOLTS
A-26085


CONSTANT GRID VOLTAGE CHARACTERISTICS
E_c = GRID VOLTAGE IN VOLTS
E_f = 6.0 V
PLATE CURRENT (I_b)
GRID CURRENT (I_c)
PLATE VOLTAGE IN VOLTS
CURRENT IN MILLIAMPERES
A-26086

PULSE MODULATOR RATINGS FOR UHF TRIODES

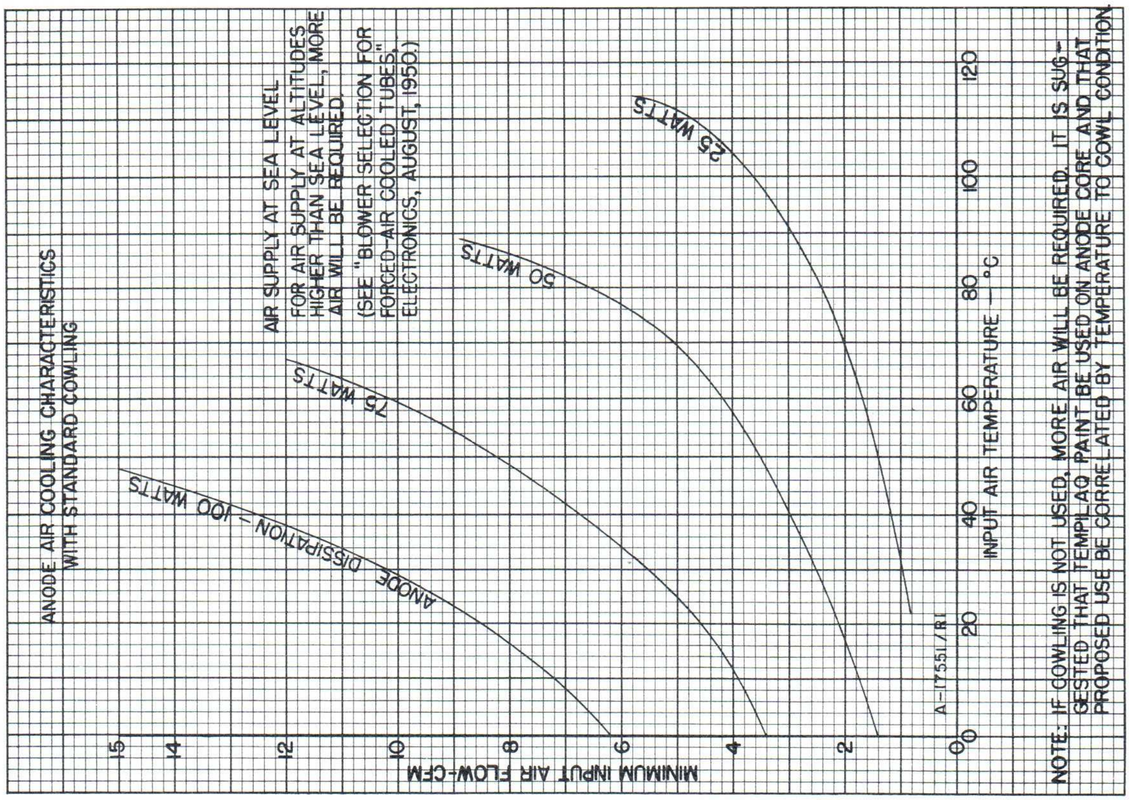


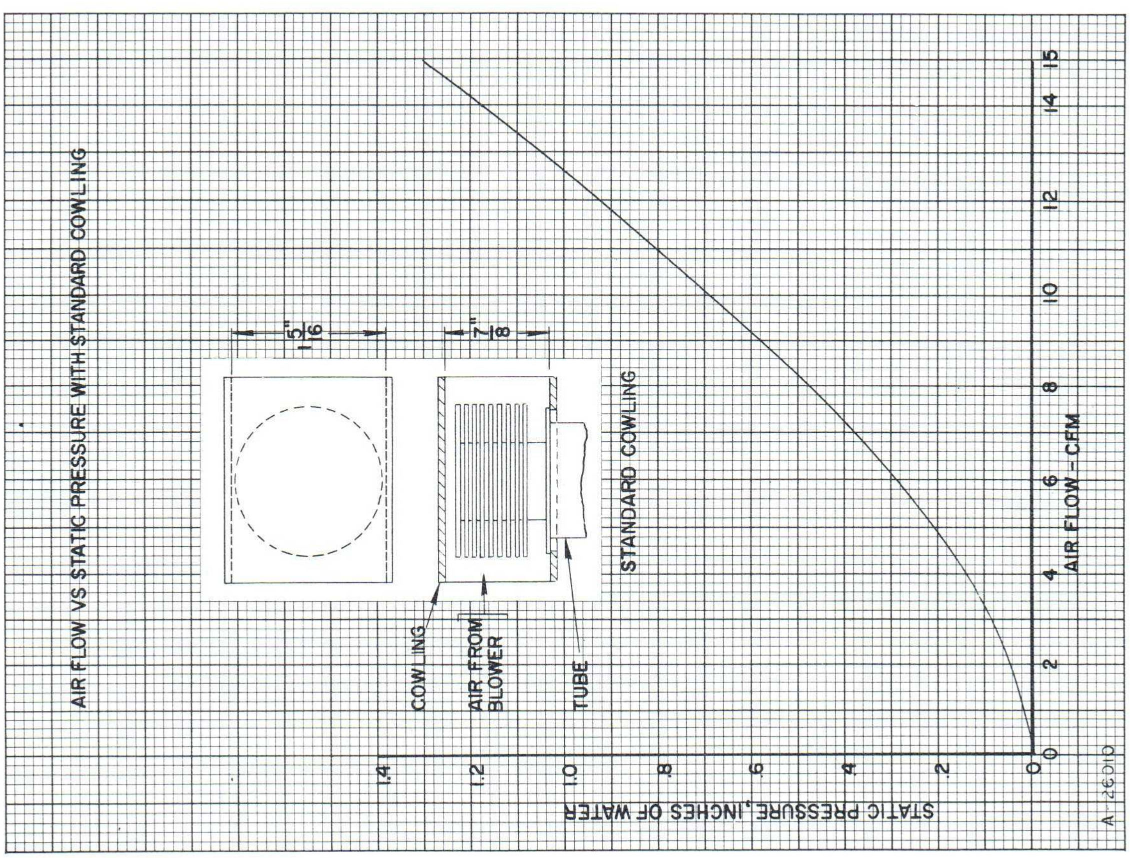
General Characteristics

Electrical	ML-7209	ML-7210	ML-7289	ML-7698	ML-7815	
Heater voltage	6.0±5%	6.3±5%	6.0±5%	6.3±5%	6.0±5%	Volts
Heater current	1.0	0.85	1.0	1.3	1.0	Amperes
Heater heating time, minimum	60	12	60	60	60	Seconds
Amplification factor*	60	55	60	50	60	
Interelectrode capacitances/without heater voltage						
Grid-Plate	2.00	2.00	2.00	2.25	2.00	pf
Grid-Cathode	6.6	5.00	6.30	8.00	6.30	pf
Plate-Cathode, maximum	0.035	0.025	0.035	0.06	0.035	pf
Maximum Ratings						
D-C plate voltage	1.5	1.5	1.0	2.0	2.0	kV
Peak plate voltage	1.8	1.8	1.2	2.5	2.5	kV
D-C grid voltage	−150	−150	−150	−150	−150	Volts
Peak positive grid voltage	250	250	250	250	250	Volts
Pulse cathode current	4.8	4.0	4.8	7.5	4.8	Amperes
D-C plate current	100	75	100	150	100	mA
Grid dissipation	1.5	1.5	1.5	1.5	1.5	watts
Plate dissipation	100	100	100	10**	10**	watts
Pulse duration	5	3	3	6	6	μs
Duty factor	0.0033	0.0025	0.0025	0.0033	0.0033	

*Cut-off Mμ

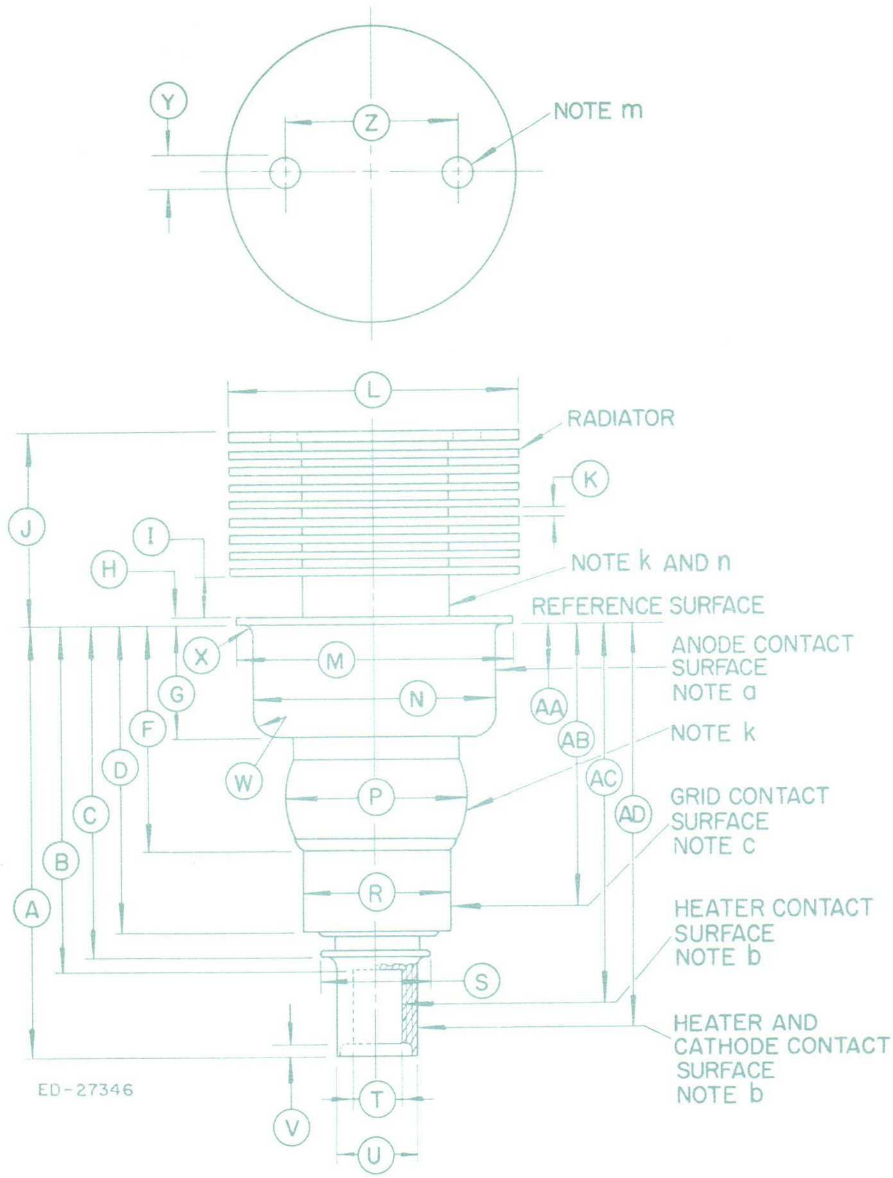
**Plate dissipation of 100 watts is possible if the tube is furnished with a forced-air cooled anode radiator.


ANODE AIR COOLING CHARACTERISTICS
WITH STANDARD COWLING
AIR SUPPLY AT SEA LEVEL
FOR AIR SUPPLY AT ALTITUDES HIGHER THAN SEA LEVEL, MORE AIR WILL BE REQUIRED.
(SEE "BLOWER SELECTION FOR FORCED-AIR COOLED TUBES," ELECTRONICS, AUGUST, 1950.)
ANODE DISSIPATION - 100 WATTS
75 WATTS
50 WATTS
25 WATTS
MINIMUM INPUT AIR FLOW-CFM
INPUT AIR TEMPERATURE — °C
A-17551/R1
NOTE: IF COWLING IS NOT USED, MORE AIR WILL BE REQUIRED. IT IS SUGGESTED THAT TEMPILAQ PAINT BE USED ON ANODE CORE AND THAT PROPOSED USE BE CORRELATED BY TEMPERATURE TO COWL CONDITION.


AIR FLOW VS STATIC PRESSURE WITH STANDARD COWLING
COWLING
AIR FROM BLOWER
TUBE
STANDARD COWLING
1 5/16"
7/8"
STATIC PRESSURE, INCHES OF WATER
AIR FLOW - CFM
A-26010

DIMENSIONS A ML-2C39A, ML-2C39WA, ML-2C41, ML-322, ML-7209, and ML-7210

DIMENSIONS B ML-322



DIMENSIONS FOR OUTLINE (INCHES)

	Dimensions A		Dimensions B	
Ref.	Min.	Max.	Min.	Max.
A	1.815	1.875	1.788	1.858
B	—	1.534	—	1.517
C	—	1.475	—	1.458
D	1.289	1.329	1.252	1.292
F	—	0.980	—	1.000
G	0.462	.477	.459	.479
H	—	.040	—	.040
I	.125	.185	.125	—
J	.766	.826	.736	.826
K	.025	.046	.015	—
L	1.234	1.264	1.235	1.265
M	1.180	1.195	1.788	1.199
N	1.025	1.035	1.021	1.039
P	—	0.812	—	.812
R	0.655	0.665	.652	.668
S	—	.545	—	.545
T	0.213	.223	.213	.223
U	.315	.325	.312	.328
V	—	.086	—	.086
W	—	.100	—	.100
X	—	.035	.105	.145
Y	.105	.145	.650	.850
Z	.650	.850		

DIMENSIONS FOR ELECTRODE CONTACT AREA (INCHES)

DIMENSIONS A

Ref.	Dimensions	Contact
AA	0.198 ± 0.163	Anode
AB	1.225 ± .040	Grid
AC	1.631 ± .097	Heater
AD	1.645 ± .170	Cathode

DIMENSIONS B

Ref.	Dimension	Contact
AA	0.195 ± .163	Anode
AB	1.210 ± .040	Cathode & Heater
AC	1.610 ± .092	Heater
AD	1.623 ± .165	Cathode & Heater

NOTES

a. The total indicated runout of the anode contact surface with respect to the cathode contact surface will not exceed 0.020 inch, except ML-322; 0.030 inch, ML-322.

b. The total indicated runout of the cathode contact surface with respect to the heater contact surface will not exceed 0.012 inch, except ML-322; 0.018 inch, ML-322.

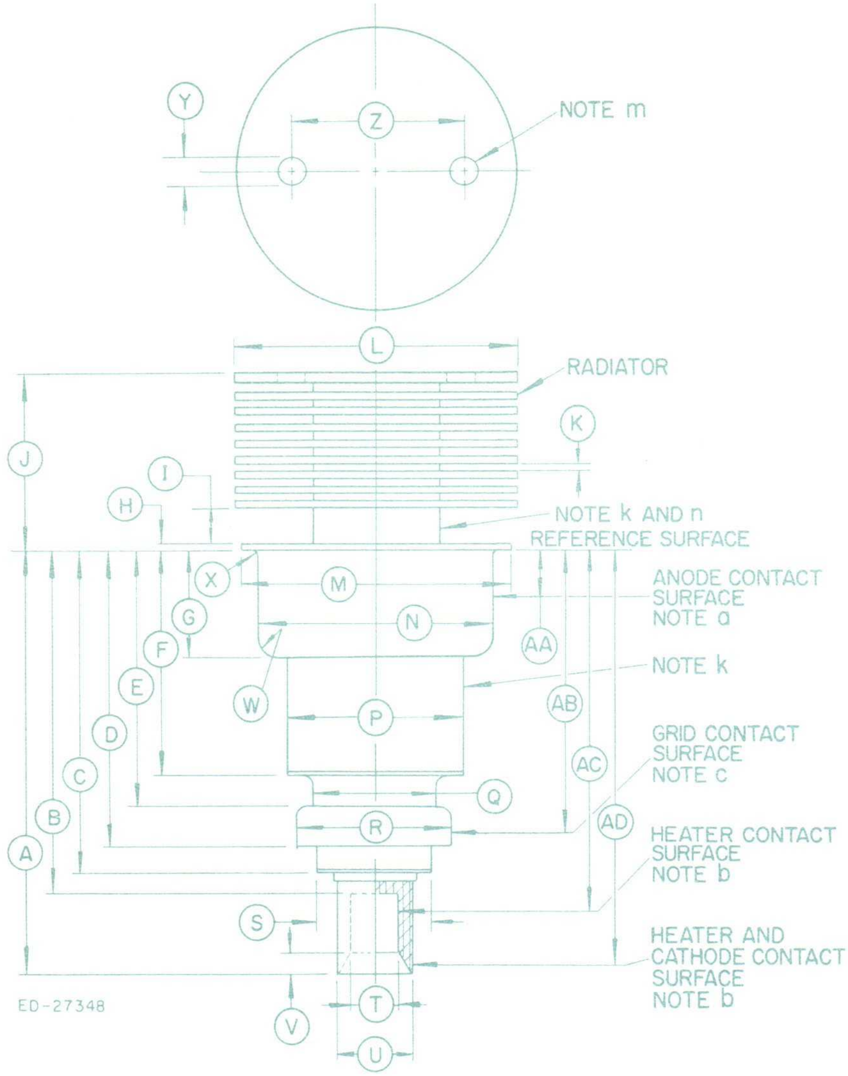
c. The total indicated runout of the grid contact surface with respect to the cathode contact surface will not exceed 0.020 inch. Does not apply to ML-322.

k. Do not clamp or locate on this surface.

m. Hole provided for tube extractor through top fin only.

n. Measure anode shank temperature here.

ML-7289/3CX100A5



DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
A	1.815	1.875
B	—	1.534
C	—	1.475
D	1.289	1.329
E	1.085	1.135
F	.880	.920
G	.462	.477
H	—	.040
I	.125	.185
J	.766	.826
K	.025	.046
L	1.234	1.264
M	1.180	1.195
N	1.025	1.035
P	.772	.792
Q	.541	.561
R	.655	.665
S	—	.545
T	.213	.223
U	.315	.325
V	—	.086
W	—	.100
X	—	.035
Y	.105	.145
Z	.650	.850

NOTES

a. The total indicated runout of the anode contact surface with respect to the cathode contact surfaces will not exceed .020 inch.

b. The total indicated runout of the cathode contact surface with respect to the heater contact surfaces will not exceed .012 inch.

c. The total indicated runout of the grid contact surface with respect to the cathode contact surface will not exceed .020 inch.

k. Do not clamp or locate on this surface.

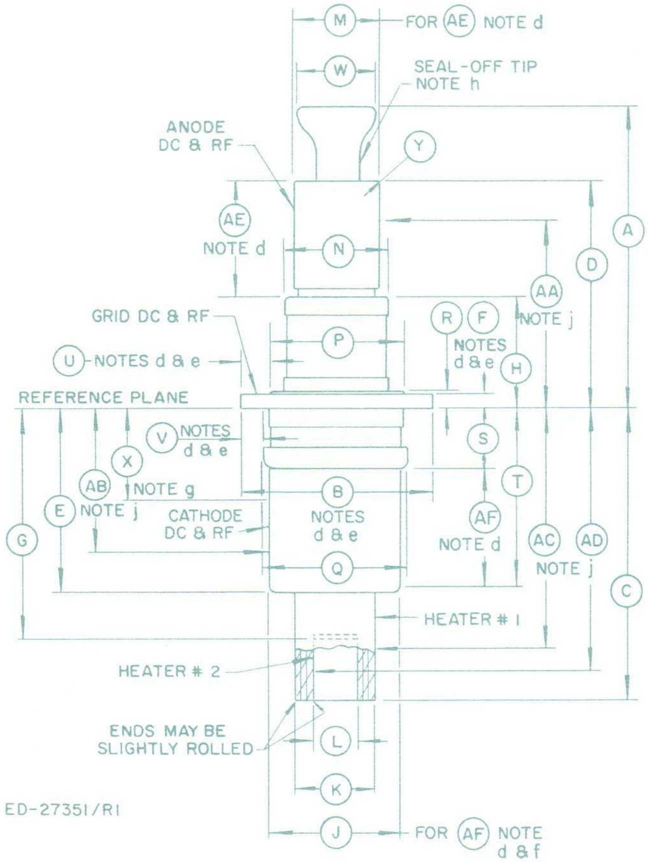
m. Hole provided for tube extractor through the top fin only.

n. Measure anode shank temperature on this surface.

DIMENSIONS FOR ELECTRODE CONTACT AREA (INCHES)

Ref.	Dimension	Contact
AA	.198 ± .163	Anode
AB	1.225 ± .040	Grid
AC	1.631 ± .097	Heater
AD	1.645 ± .170	Cathode

ML-6442 and ML-6771



DIMENSIONS IN INCHES

Dim.	Limits Minimum	Maximum	Nominal
A	—	1.328	—
B	0.810 dia.	0.818 dia.	—
C	1.219	1.281	—
D	0.953	0.984	—
E	0.750	0.813	—
F	0.070	0.078	—
G	—	1.016	—
H	—	0.515	—
J	0.539 dia.	0.549 dia.	—
K	0.318 dia.	0.328 dia.	—
L	0.180 dia.	0.190 dia.	—
M	0.365 dia.	0.371 dia.	—
N	—	0.453 dia.	—
P	0.560 dia.	0.570 dia.	—
Q	—	0.609 dia.	—
R	0.077	0.097	—
S	—	0.266	—
T	0.719	—	—
U	—	—	0.094
V	—	—	0.094
W	—	0.313	—
X	—	0.375	—
Y	—	—	0.016 rad.
AA	—	—	0.750
AB	—	—	0.547
AC	—	—	1.000
AD	—	—	1.109
AE	—	—	0.438
AF	—	—	0.453

NOTES

d. Contact surfaces shall be confined to this area.

e. Only these surfaces shall be used for tube stops or clamping.

f. Maximum diameter is not increased by solder.

g. Tube marking is confined to this area.

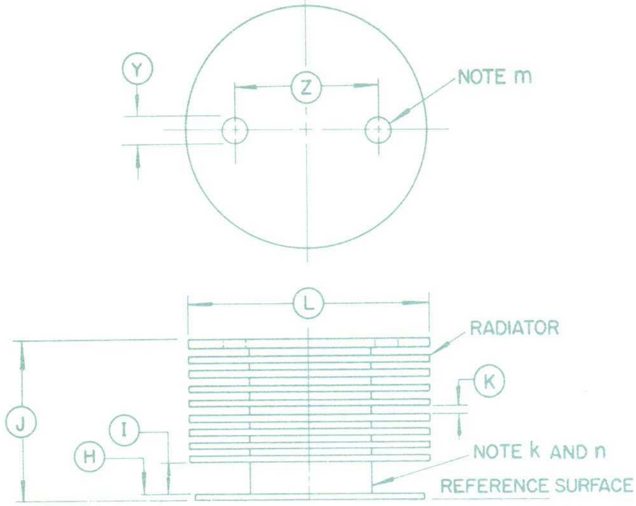
h. Exhaust tubulation must not be subjected to any mechanical stress.

j. Eccentricity is gaged at points designated and falls within the following limits:

Contact	Eccentricity*	Reference
Anode	0.010 max.	Grid Contact
Cathode	0.010 max.	Grid Contact
Heater No. 1	0.015 max.	Grid Contact
Heater No. 2	0.015 max.	Grid Contact

*Eccentricity is one-half total indicated runout.

ML-7211 and ML-7815R



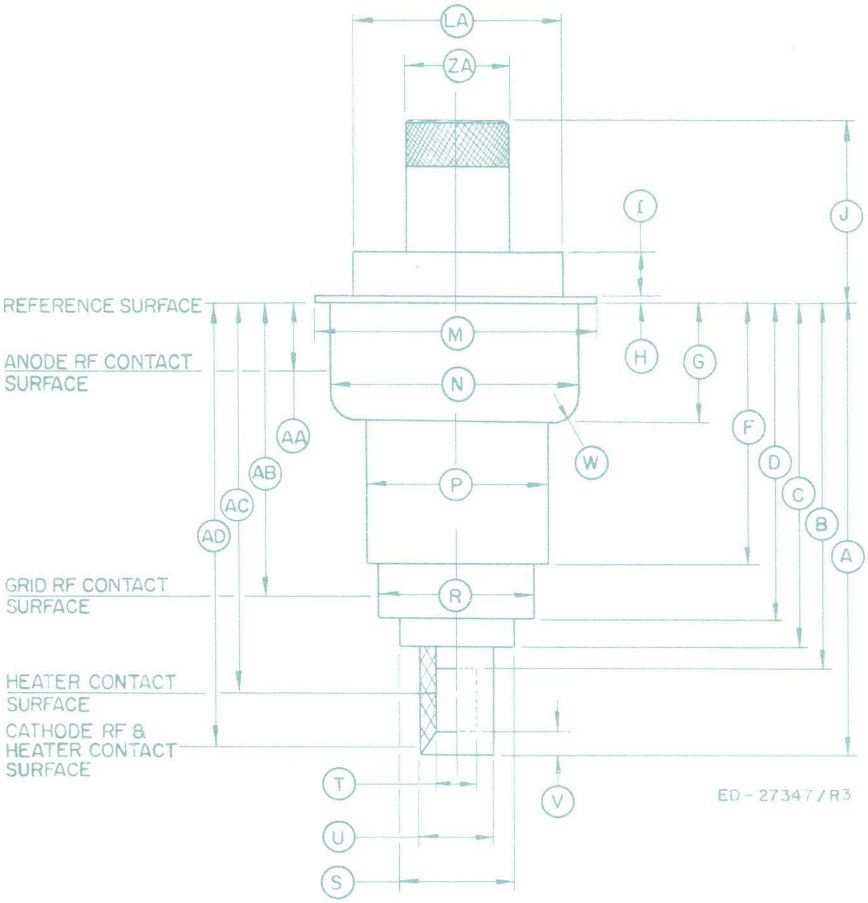
ML-7211 AND ML-7815R DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
H	—	.040
I	.125	.185
J	.766	.826
K	.025	.046
L	1.234	1.264
Y	.105	.145
Z	.650	.850

Note

All other outline dimensions of the ML-7211 and ML-7815R are the same as those given below.

ML-7698 and ML-7815/3CPN10A5



DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
A	1.815	1.875
B	—	1.534
C	—	1.475
D	1.289	1.329
F	0.970	1.010
G	0.462	0.477
H	—	0.040
I	—	0.185
J	0.766	0.826
LA	0.840	0.860
M	1.180	1.195
N	1.025	1.035
P	0.752	0.792
R	0.655	0.665
S	—	0.545
T	0.213	0.223
U	0.315	0.325
V	—	0.086
W	—	0.100
ZA	0.427	0.447

NOTES

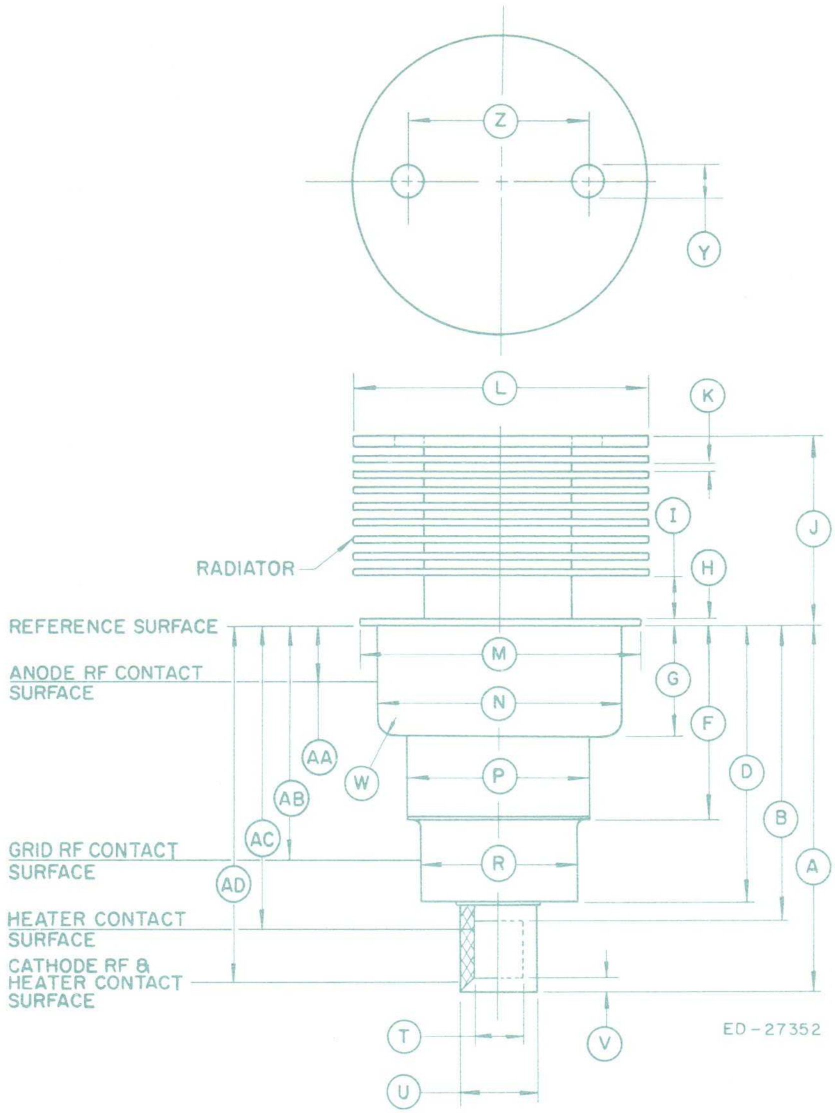
1. The total indicated runout of the anode and grid contact surfaces with respect to the cathode contact surface will not exceed .020.
2. The total indicated runout of the cathode contact surface with respect to the heater contact surface will not exceed .012.

ML-7815R has dimensions identical to those of ML-7211.

DIMENSIONS FOR ELECTRODE CONTACT AREA (INCHES)

Ref.	Limits	Contact
AA	.198 ± .163	Anode
AB	1.225 ± .040	Grid
AC	1.631 ± .097	Heater
AD	1.645 ± .170	Cathode

ML-7855



DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
A	1.500	1.560
B	—	1.214
D	1.125	1.165
F	0.800	0.840
G	0.462	0.477
H	—	0.040
I	0.125	0.185
J	0.766	0.826
K	0.025	0.046
L	1.234	1.264
M	1.180	1.195
N	1.025	1.035
P	0.752	0.792
R	0.655	0.665
T	0.213	0.223
U	0.315	0.325
V	—	0.086
W	—	0.100
Y	0.105	0.145
Z	0.650	0.850

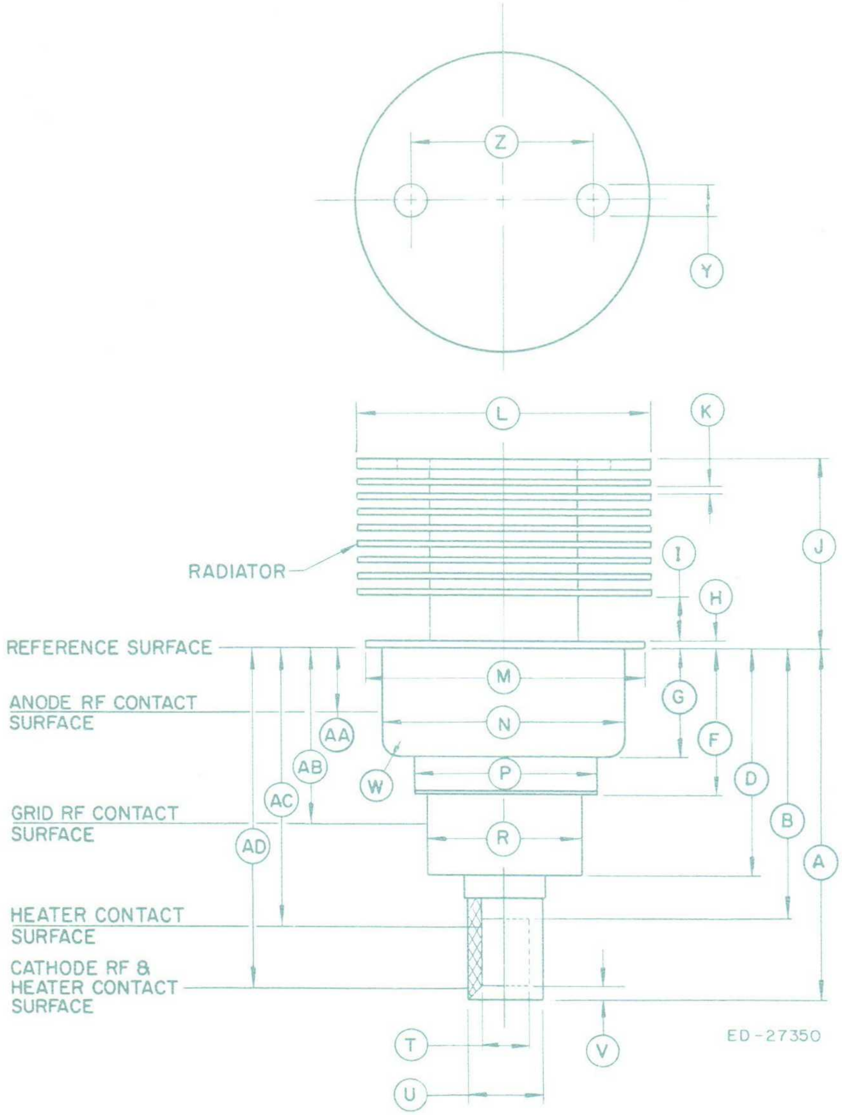
NOTES

1. The total indicated runout of the anode and grid contact surfaces with respect to the cathode contact surface will not exceed 0.020 inch.
2. The total indicated runout of the cathode contact surface with respect to the heater contact surface will not exceed 0.012 inch.

DIMENSIONS FOR ELECTRODE CONTACT SURFACES (INCHES)

Ref.	Dimension	Contact
AA	0.198 ± 0.163	Anode
AB	1.061 ± 0.040	Grid
AC	1.316 ± 0.097	Heater
AD	1.330 ± 0.170	Cathode

ML-518



DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
A	1.447	1.507
B	—	1.166
D	0.940	0.980
F	0.605	0.645
G	0.462	0.477
H	—	0.040
I	0.125	0.185
J	0.766	0.826
K	0.025	0.046
L	1.234	1.264
M	1.180	1.195
N	1.025	1.035
P	0.752	0.792
R	0.655	0.665
T	0.213	0.223
U	0.315	0.325
V	—	0.086
W	—	0.100
Y	0.105	0.145
Z	0.650	0.850

NOTES

1. The total indicated runout of the anode and grid contact surfaces with respect to the cathode contact surface will not exceed 0.020 inch.
2. The total indicated runout of the cathode contact surface with respect to the heater contact surface will not exceed 0.012 inch.

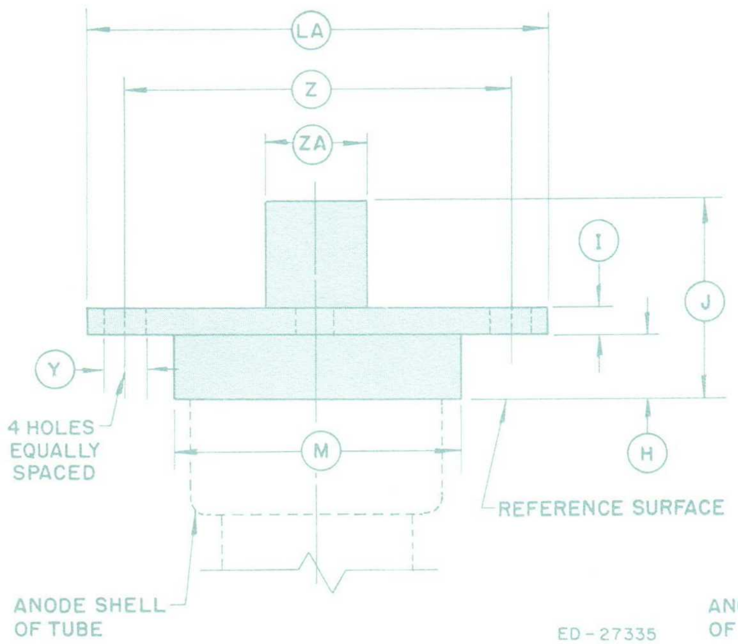
DIMENSIONS FOR ELECTRODE CONTACT SURFACES (INCHES)

Ref.	Dimension	Contact
AA	0.198 ± 0.163	Anode
AB	0.876 ± 0.040	Grid
AC	1.263 ± 0.097	Heater
AD	1.277 ± 0.170	Cathode

HEAT SINK HS-1, CATALOG OUTLINE

ML-2C39A, ML-2C39WA, ML-2C41, ML-3CPN10A5, ML-3CX100A5, ML-322, ML-7209, ML-7210, ML-7211, ML-7289, ML-7698, ML-7815.

HEAT SINK HS-1 (CAT. NO. P-26378)



HS-1 DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
H	0.270	0.280
I	—	0.140
J	0.765	0.869
LA	1.893	1.913
M	1.180	1.195
Y	0.170	0.190
Z	1.583	1.603
ZA	0.427	0.447

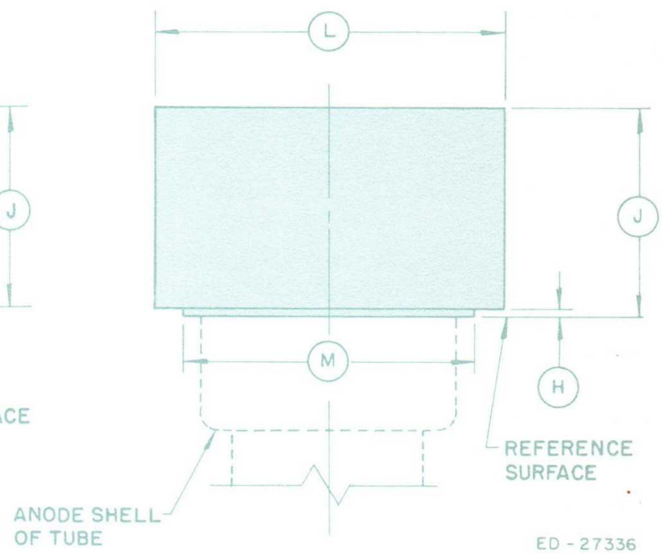
HEAT SINKS HS-2 AND HS-3, CATALOG OUTLINE

ML-2C39A, ML-2C39WA, ML-2C41, ML-3CPN10A5, ML-3CX100A5, ML-322, ML-7209, ML-7210, ML-7211, ML-7289, ML-7698, ML-7815, ML-7855 (Use HS-2).

ML-518, (Use HS-3)

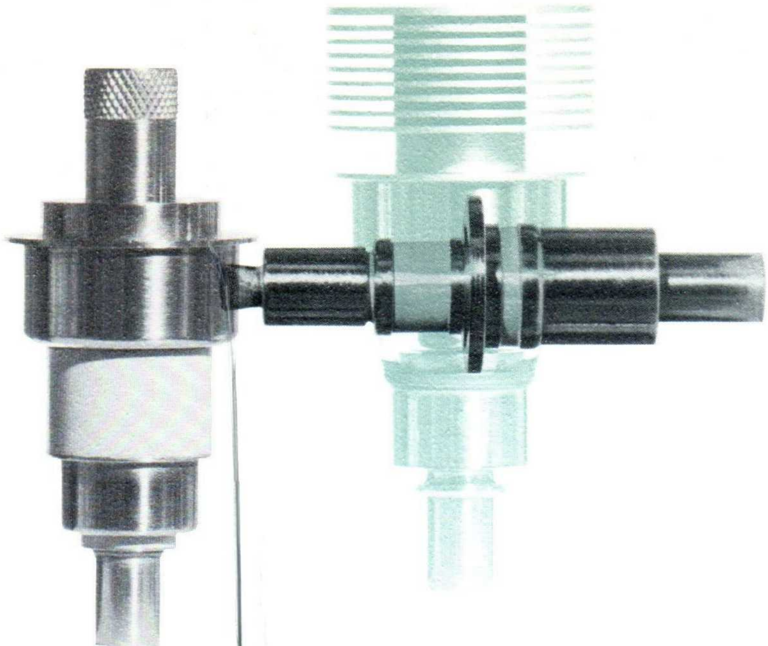
HEAT SINK HS-2 (CAT. NO. P-27491)

HEAT SINK HS-3 (CAT. NO. P-27490)



HS-2 & HS-3 DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Minimum	Maximum
H	0.025	0.045
J	0.843	0.883
L	1.421	1.454
M	1.180	1.195



Developmental Tube Types*
Design Objectives

	C-Band Pulsed Planar Triode	S-Band Pulsed Planar Triode	
Filament Voltage	6.0	6.3	Volts
Filament Current	1.0	3.0	Amps
Heater . . . Heating Time	60	120	Seconds
Amplification Factor	85	—	
Transconductance	—	25,000	umhos
Interelectrode Capacitances Approximate			
Grid-Plate	4	4.5	pf
Grid-Filament	12	17	pf
Duty	.001	.001	
Maximum Ratings			
Pulse Length	1	3	usec
Peak Plate Voltage	3	3.5	kV
Peak Plate Current	7	12	amp
Grid Bias Voltage	—	−150	volts
Plate Dissipation	20	250	watts
Grid Dissipation	1	1	watt
Frequency of Operation	6	3	Gc
Peak Power Output, approximate	3	10	kw

*The technical descriptions given herein represent feasible tube designs; The Machlett Laboratories does not necessarily assume the commitment to develop or produce these tubes.

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