

# Tube RP Values

...by Earles L. McCaul

## • Rule-of-thumb Values

**TRIODES:**  $RL \approx 2\text{-to-4}$  times  $r_p$

**TETRODES, PENTODES:**  $RL \approx 1/6\text{-to-}1/10$  of  $r_p$

Use lower  $r_p$  values for lower distortion, %THD.

Use higher  $r_p$  values for higher output power,  $P_o$ .

Excerpted from John D. Ryder<sup>[1]</sup>:

“11-5. Maximum power output – pentodes and triodes.

The distortion generated and the possible power output are both functions of the load assigned to the amplifier. Use of the condition  $RL = r_p$  will furnish maximum possible power for a given input signal, but the amplitude distortion produced with the load will usually be greater than considered allowable. Higher values of load, which permit greater driving voltages, may raise the power output and may increase or decrease the distortion. As used, loads for **triodes** are usually in the range of **two-to-four** times the value of the plate resistance, and a small fraction (**1/6 – 1/10**) of the plate resistance for **pentode** and **beam** tubes.”

“The maximum percentage of distortion allowed is arbitrary, since it is dependent on subjective factors. Usually a maximum of **5-percent** distortion is considered permissible, although only 1 or 2 percent is tolerated in high-fidelity service.”

See 6L6 and 6V6 tube data sheet graphs for illustrations of  $P_o$  and %THD versus  $RL$  curves and observe how “rated load”—usually  $5k\Omega$  with  $V_p = V_s = 250V$ —does **not** coincide with either *minimum* distortion or *maximum* output power!

## • Theoretical Values

Excerpted from F. E. Terman<sup>[2]</sup>:

“1. To the extent that  $\mu$  ( $\mu$ ) is constant and that Eq. (6-10) is true, the plate resistance ( $r_p$ ) depends on the plate current ( $I_p$ ),

Eq. 6-10:  $I_p = K \cdot (V_g + V_p / \mu)^{3/2}$

and is inversely proportional to  $I_p^{1/3}$ . This can be demonstrated by substituting Eq. (6-10) into Eq. (6-14)

---

<sup>1</sup> John D. Ryder, **ELECTRONICS FUNDAMENTALS AND APPLICATIONS**, 3<sup>rd</sup> Ed., 1964, Prentice-Hall; Chapter 11 – Class A and B Amplifiers with Large Signals.

<sup>2</sup> F. E. Terman, , **ELECTRONIC AND RADIO ENGINEERING**, 4<sup>th</sup> Ed., 1944, McGraw-Hill; Chapter 6, footnote at bottom of page 188.

Eq. 6-14:  $r_p = \mu/g_m$

and noting that:

Eq. 6-(\*) :  $(V_g + V_p/\mu)^{1/2} = (I_p/K)^{1/3}$

This enables one to write:

Eq. 6-15:  $r_p = \delta V_p/\delta I_p = 1/(\delta I_p/\delta V_p) = 2\mu/[3K(V_g + V_p/\mu)^{1/2}]$

$r_p = 2\mu/[3K^{2/3} \cdot I_p^{1/3}]$ "

The Terman excerpts tell us three important facts: (1) effective voltage (left side of Eq. 6-(\*)) varies as the square root while effective current (right side of Eq. 6-(\*)) varies as the cubic root; (2) that square-root of effective voltage equals the cubic-root of plate current; and, (3) plate resistance varies inversely with the cubic root of plate current.

However, because Eq. (6-15) is actually for triodes, a slight adjustment is necessary for beam tetrodes and pentodes. For these tubes, the combined plate current and screen current ( $I_p + I_s$ ) is used and the screen voltage ( $V_s$ ) is substituted<sup>[3]</sup> for plate voltage ( $V_p$ ), which is then dropped from the equation. Thus the revised Eq. (6-15) for beam tetrodes and pentodes become:

$r_p = 2\mu/[3 \cdot K^{2/3} \cdot (V_g + V_s/\mu)^{1/2}]$

$r_p = 2\mu/[3 \cdot K^{2/3} \cdot (I_p + I_s)^{1/3}]$

Note the following equivalences are applied here:

$r_p = \mu/g_m = (\delta V_p/\delta V_g)/(\delta I_p/\delta V_g) = \delta V_p/\delta I_p$

$r_p = \mu \times (1/g_m)$

**TRIODE:**

$1/g_m = 2/[3 \cdot K \cdot (V_g + V_p/\mu)^{1/2}]$

$1/g_m = 2/[3 \cdot K^{2/3} \cdot I_p^{1/3}]$

$r_p = \mu \times (1/g_m)$

**TETRODE/PENTODE:**

$1/g_m = 2/[3 \cdot K^{2/3} \cdot (V_g + V_s/\mu)^{1/2}]$

$1/g_m = 2/[3 \cdot K^{2/3} \cdot (I_p + I_s)^{1/3}]$

$r_p = \mu \times (1/g_m)$

---

\* Terman does not uniquely identify this equation in the footnote; it is Eq. 6-10 rearranged with separated 1/2 and 1/3 powers.

<sup>3</sup> In beam tetrodes and pentodes the effective screen voltage ( $V_s/\mu_1$ ) has much more control over plate current than does the effective plate voltage ( $V_p/\mu_2$ ). This occurs because tetrode and pentode plate  $\mu$  ( $\mu_2$ ) values are routinely magnitudes greater than their screen  $\mu$  ( $\mu_1$ ) values; example: 6L6  $\mu_1 = 7.99$  and  $\mu_2 = 135$ .

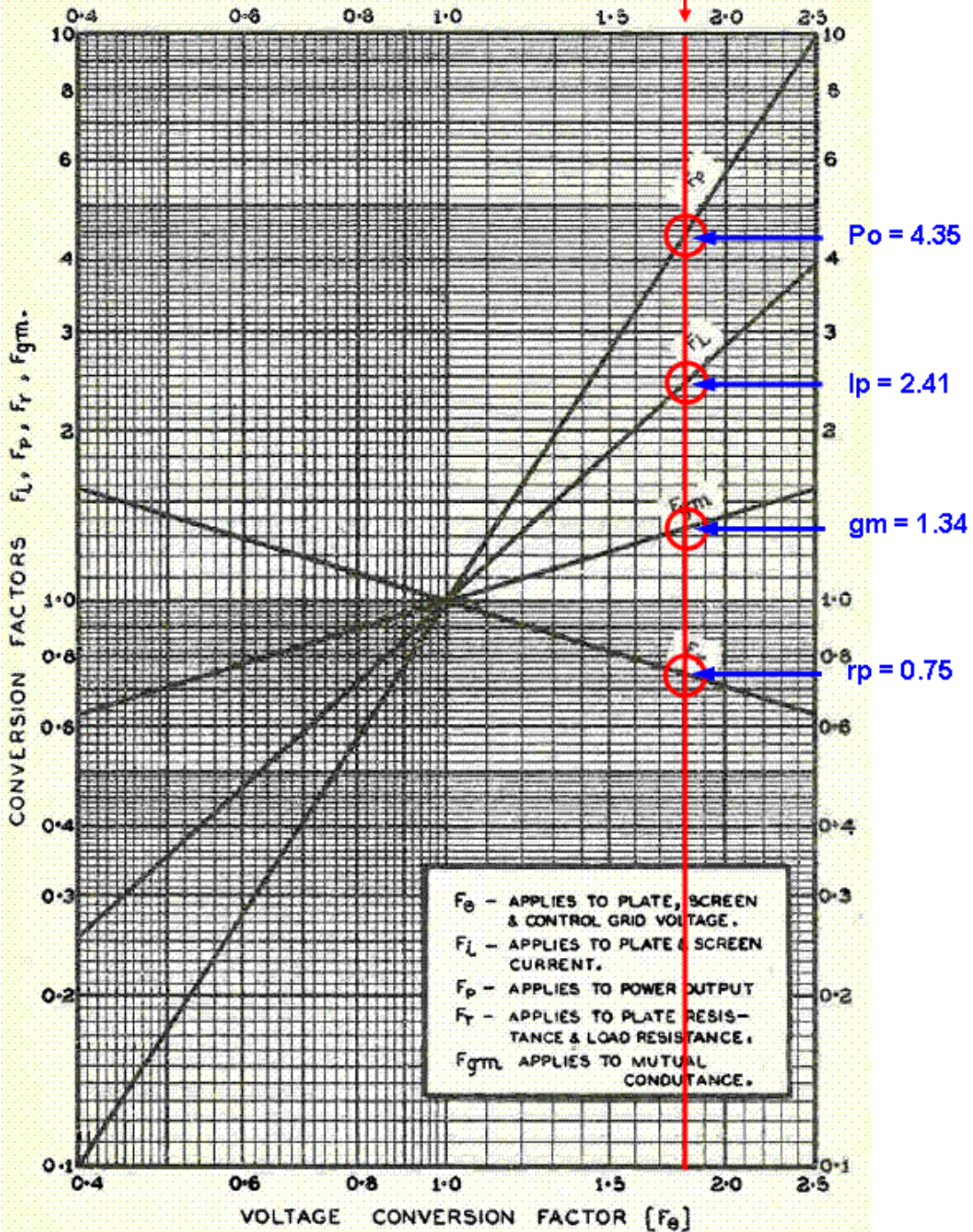
Perveance (K) has the units of amps-per-volt<sup>2/3</sup> and interestingly is the same value for 6L6 and 6V6 tubes, **0.0010 A/V<sup>2/3</sup>**; however, this value is normally different for different tubes and often varies from manufacturer to manufacturer (see Finding Perveance article). Using the above equations, you can estimate rp under actual circuit conditions.

- **Nomograph Values**

Information on how to use nomographs to ‘scale’ published rp values to *new* operating conditions can be found in the following sources:

- 1) “Valve Conversion Factor Chart,” Chapter 40, page 329, in **RDH3** (1944).

Valve Conversion Factor Chart **1.8 = 450V/250V**



The Chart is based on the following relations:

$$F_{gm} = F_0^{1/2} = \sqrt{F_0}$$

$$F_L = F_0^{3/2} = \sqrt{F_0^3} = F_0 \sqrt{F_0} = F_0 F_{gm}$$

$$F_P = F_0^{5/2} = \sqrt{F_0^5} = F_0^2 \sqrt{F_0} = F_0 F_L$$

2) Fig. 44 – Nomograph of tube conversion factors, page 33, in **RCA Receiving Tube Manual**, RC-30 (1975).

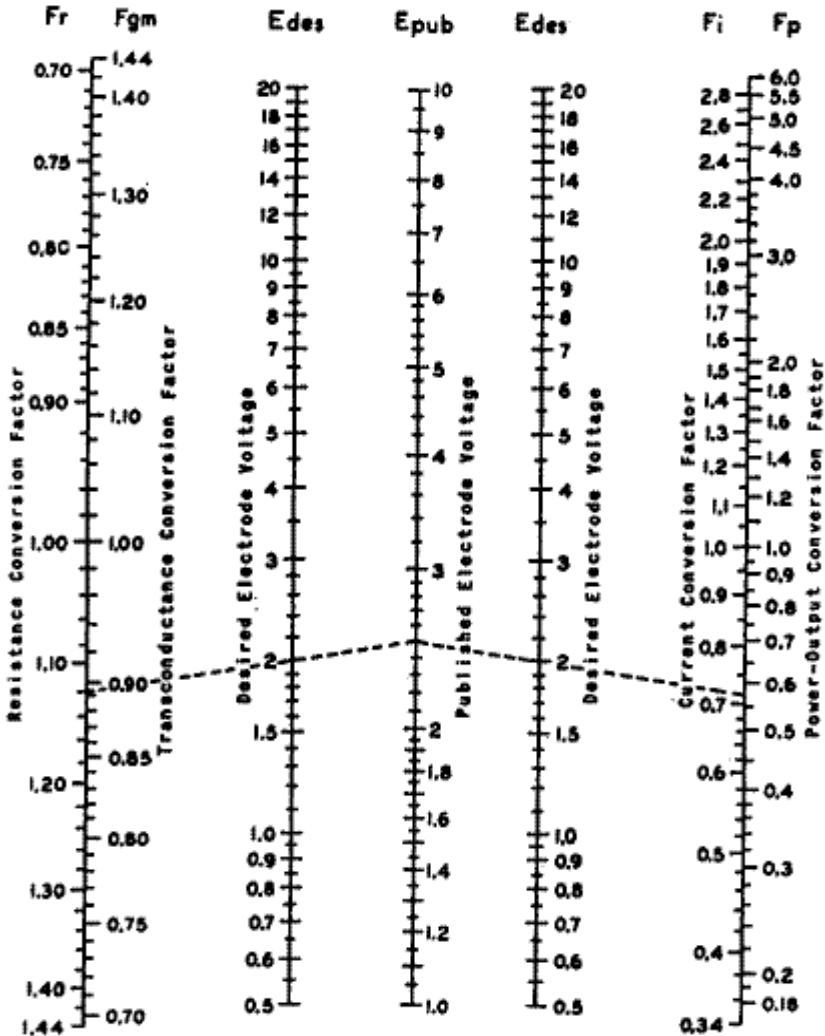
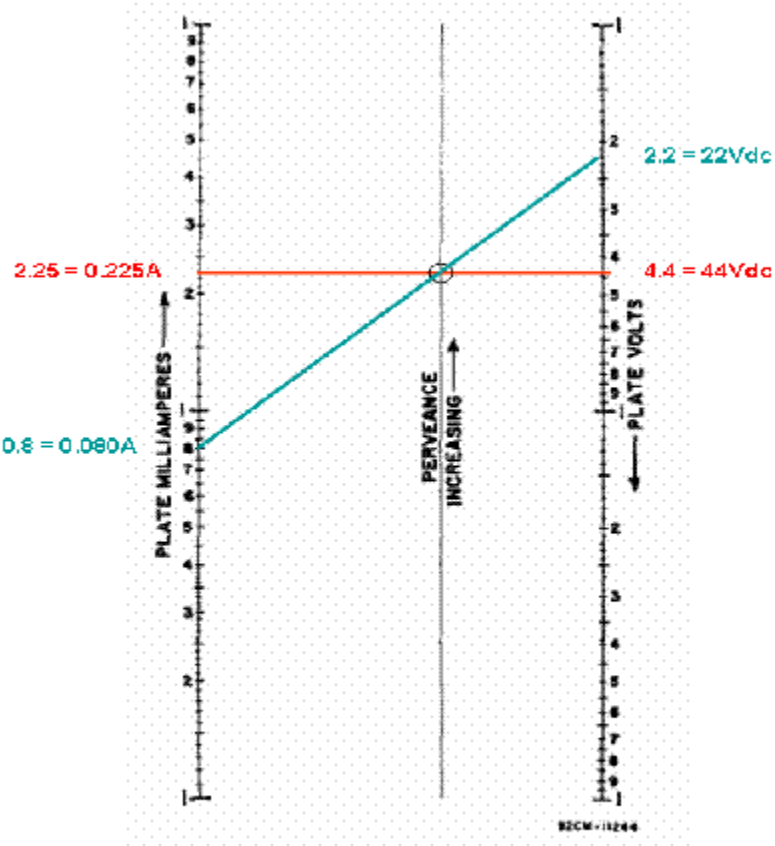


Fig. 44—Nomograph of tube conversion factors.

3) Fig. 125 – Diode Perveance Nomograph, page 96, in **RCA Receiving Tube Manual, RC-30** (1975).



*Fig. 125—Diode perveance nomograph.*

Fig. 8-10 and pages 255-256 in Chapter: Audio-Frequency Power Amplifiers, in J.D. Ryder, **ENGINEERING ELECTRONICS**, 1<sup>st</sup> Ed., 1957, McGraw-Hill.