70-Percent Plate Dissipation Rule…by Earles L. McCaul

• Class-AB_1 Plate Dissipation at Idle

A widely-used design rule says that the power tubes in a Class-AB power amplifier should be biased so that their zero-signal (idle) plate dissipation is no more than 70 percent of the maximum plate dissipation for one tube[1]. Here we will graphically examine why this rule works.

At idle, both tubes in a push-pull amplifier are conducting at a low, steady level—their plate voltages and currents are equal and constant. Each tube has a quiescent (suffix $_q$) plate dissipation equal to its idle plate voltage times its idle plate current:

$\mathbf{Pp_q = Vp_q \times Ip_q}$ …in average [2] watts.

In a push-pull amplifier operating at maximum power, each tube conducts only about half the time. For a pure sine wave input, for example, a tube conducts about 180 degrees out of 360 degrees, with perhaps a 20-degree overlap when both tubes are conducting. Each tube's average plate current is only about half of the average current flowing through the output transformer primary over a complete cycle.

Figure 1 is a plate current versus plate voltage graph with a 30-watt maximum plate dissipation curve (heavy solid **purple**) superimposed. This would be the 100-percent plate dissipation curve for a 6L6GC beam power tetrode, for example. Anywhere along this curve the plate voltage times the plate current equals 30 watts.

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1 See, for example, "Idle Current Biasing - Why 70 percent?" on the Aiken Amplification website.

2 Average (0.6366) power is the effective **heating** equivalent of peak power. RMS (0.7071) is the effective equivalent of peak **sinusoid** voltage or current values only; their product being average power in watts.

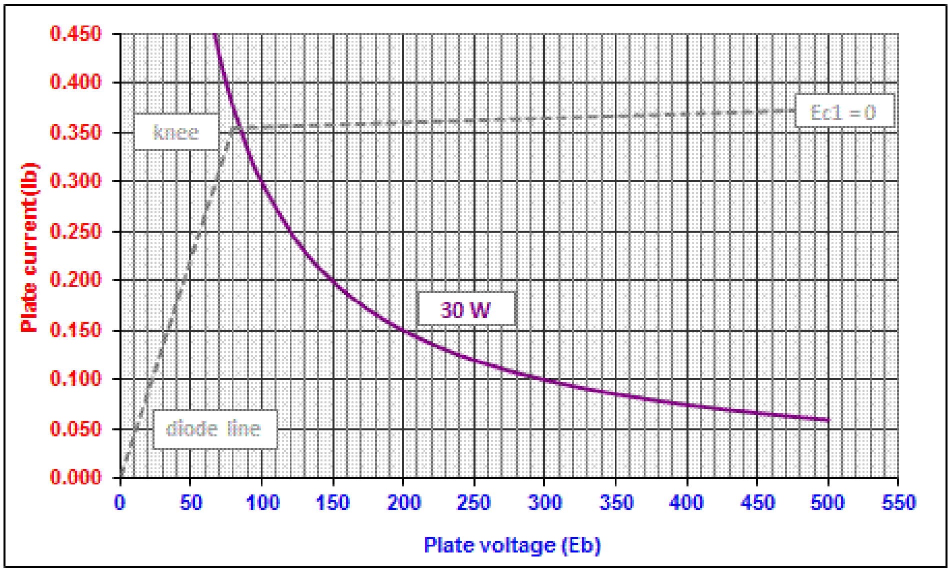

Figure 1 - 100% (30W) plate dissipation line.

In Figure 2, a 70-percent dissipation curve (thin dashed **purple**) has been superimposed onto the graph. Anywhere along this curve the plate is generating 21 watts (70% of 30W) of wasted heat.

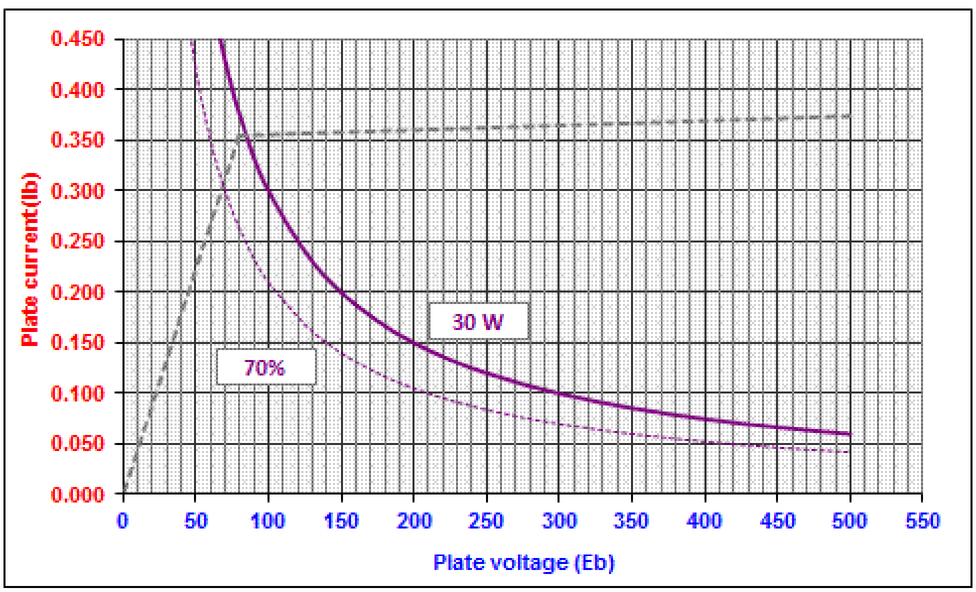

Figure 2 - 70% (21W) plate dissipation line.

• The Ip_q and $Ip_{(pk)}$ Load Line Method

Next we draw a load line on the graph between the two operating conditions of idle and maximum-signal. Here we are using the 55W Class-AB_1 push-pull amplifier example in the

RCA 6L6GC datasheet [3] adjusted for 70-percent operation, but the steps described work for any Class AB amp.

The zero-signal (idle) condition for the RCA example has a plate voltage of $450V_{DC}$ and a plate current of $47mA_{DC}$ per tube. This is designated point **A** and is located at **47mA@450V** on the graph shown in Figure 3.

The maximum-signal **current** condition is the *combination* of $Ip_{(pk)}$ and Ipq. For the RCA example, this is 297mA peak maximum-signal plate current—peak value of the $210mA_{RMS}$ value—and 47mA of idle plate current, or 344mA.

The maximum-signal **voltage** condition is the *difference* between the idle plate voltage and the peak plate voltage change. For the RCA example, this is $450V_{DC}$ at idle minus $370V_{(pk)}$, — peak value of the $262V_{RMS}$ value—or, $80V_{DC}$. This is designated point **B** and is located at **334mA@80V** on the graph in Figure 3. The line drawn between point **A** and point **B** is the AC-signal load line (heavy solid **brown**) representing the effective 1.25k ohm load impedance presented to each power tube.

In this case, point **B** coincides with the "knee," the point where the tube diode line and zero-grid plate curve intersect, but this is not always the case. The "knee," however, is the limiting condition for both plate current and voltage at maximum output power. The graph in Figure 3 locates $\mathbf{Ip_q@Vp_q}$ at point **A** and $\mathbf{Ip_{(pk)}@Vp_{(pk)}}$ at point **B** and the 1.25k ohm load line between them.

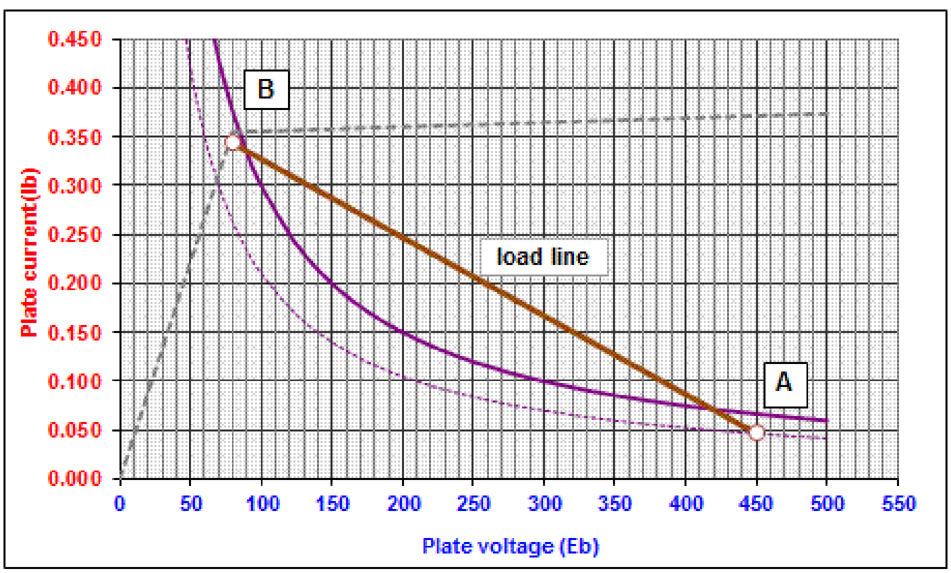

Figure 3 – AC-signal load line between A and B.

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[3] RCA 6L6-GC Beam Power Tube data sheet (8-60).

The next graph adds point **C** to represent how each tube conducts only about half the time when the amplifier is operating at full power. It represents how at maximum power each tube is alternating between maximum-signal current and deep cutoff, a condition that causes the time-averaged current load through each tube to be about one-half [4] of the total maximum-signal current.

For the RCA example, which has a maximum-signal plate current of 344mA at point **B**, the point **C** value is one-half of that value, or 172mA, and is located directly below point **B** on the same 80V ordinate. Point **C** is shown located at **172mA@80V** on the graph in Figure 4.

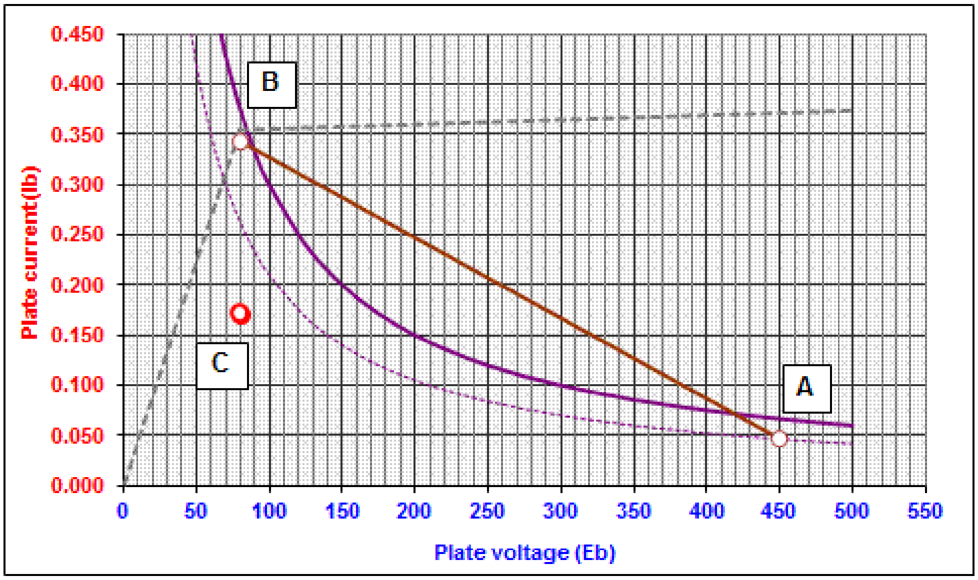

Figure 4 – Half of maximum-signal plate current point.

Now we draw a line (heavy solid **red**) connecting point **A** to point **C**, called the tangent line. Recalling that point **A** is the idle point at 70-percent of maximum plate dissipation where each tube has 21 watts of plate dissipation when there is no input signal and that point **C** represents how each tube sees only one-half of the maximum-signal plate current, the tangent line between these two points represents **all** power levels between idle and maximum power. This tangent line is shown in red in Figure 5.

[4] A simple approximation; actual conduction angle of 198 degrees is 55%.

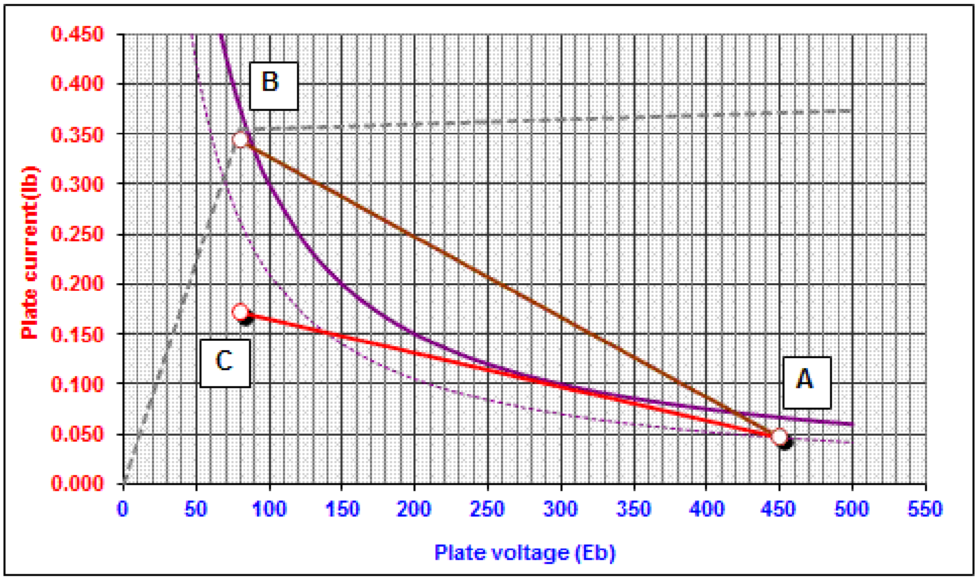

Figure 5 – The tangent line between points A and C.

• Summary

In other words, 70 percent of maximum plate dissipation is the idle condition at which the average [4] plate operating power barely reaches the maximum plate dissipation curve but does not cross above it at any time. We see that maximum plate dissipation is never exceeded at any operating power level. If we were to use a higher idle plate current, however, then the maximum could be exceeded, at least momentarily, at some power levels.

The final graph shown in Figure 6 provides a closer view of the area of the **A**-to-**C** tangent line and how it indeed just barely "grazes" but does not cross above the 100-percent dissipation line at any time.

Points **A** and **B** must never be located *above* the 100-percent plate dissipation line.

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[4] Plate dissipation is average power. Average (0.6366) power is the effective **heating** equivalent of peak power. RMS (0.7071) is the effective equivalent of peak **sinusoid** voltage or current values only; and their product is average power in watts.

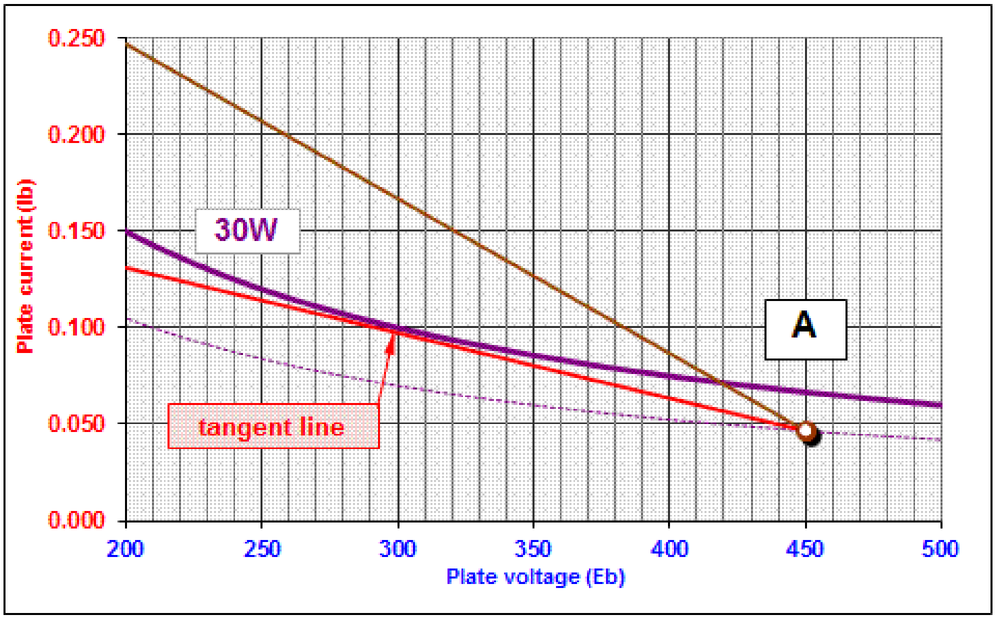

Figure 6 - Close-up view of tangent line grazing 30W dissipation line.

• Conclusion

When we simply invoke the 70-percent plate dissipation rule, we do not need to follow all the steps we have just demonstrated. What this procedure has shown, however, is that an upper limit of 70-percent ensures that the amplifier never exceeds the maximum plate dissipation rating of the tube. This is why it is often recommended to adjust the grid bias voltage of a class AB power amplifier so that the power tubes idle at no more than 70-percent maximum plate dissipation.