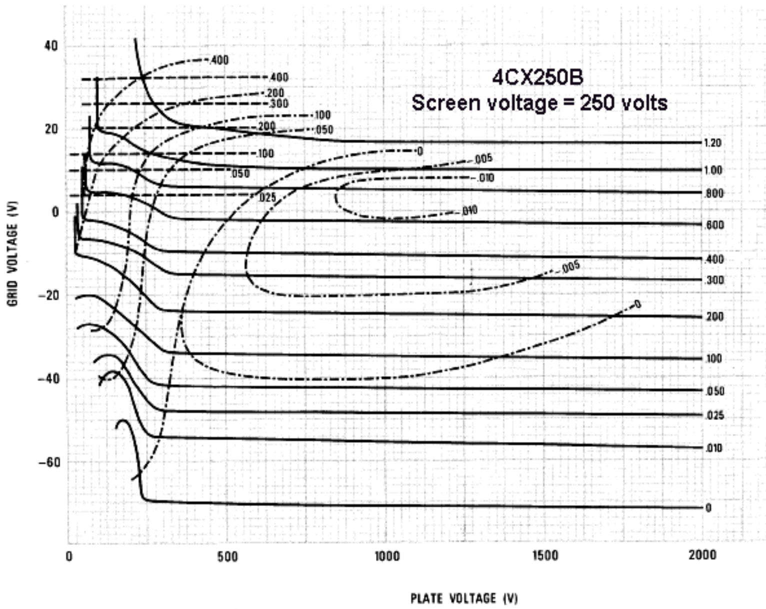
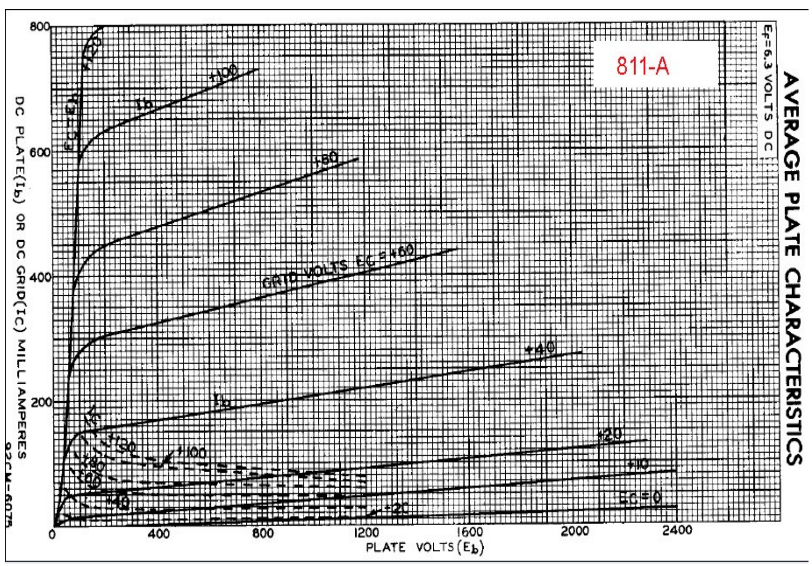
Use of the Program "TubeCalculator.exe"

To use the tube calculator, characteristic curves for the tube must be available. These are graphs which show the currents drawn by the grid, screen and plate based on the voltages on them. Curves for many popular amateur tubes are included in the program. High power tubes for broadcast are also included in a second file named "broadcast tubes". To access these, save the contents of "bmp library" with another name, and rename the file "broadcast tubes" as "bmp library". Or you can drag all files into the "bmp library" folder. If curves are not included for the tube you wish to analyze, you must provide them.



Finding curves for the tube of interest:

Tube curves are of two types. The easier to use are the "constant current curves" typically supplied by Eimac. These plot plate voltage on the bottom axis and grid voltage on the left axis. The curves themselves show values of grid, screen and plate current. For triodes, only one set of curves per tube is needed. For tetrodes and pentodes, several sets of curves are usually provided showing performance with various values of screen voltage. Be sure you use the curves for the screen voltage you will use.



The second type of curves plot plate volts on the bottom axis and plate current on the left axis with the curves themselves representing grid volts. Sometimes, grid current curves are also provided. These are referred to as Ip/Ep curves. This software, unlike the purely graphical method, allows useful calculations to be done with this type of curves, but it is a bit more complicated than using the constant current curves. However, since many older tube types, such as the 811A and surplus Russian triodes, may have only this type of curves, it is useful to understand both methods. It is possible to convert Ip/Ep curves to the constant current type and this has been done for several types, including the 811A, the GI7B and the GS35B.

Some companies, for example Brown Boveri, have supplied tube curves in both formats. These are useful in trying out both methods. The results should be the same, but doing both will give you confidence in doing the Ip/Ep method when you have no other option. Also, the Brown Boveri data may include types similar to RCA types for which only the Ip/Ep curves exist. For example, the T50-1 is somewhat like the 811A, which is a popular type for which only Ip/Ep curves exist. The bias needed for the two tubes is different, but the loading and output parameters are similar.   In a few cases, for example, the 4CX250B, RCA has provided both types of curves.

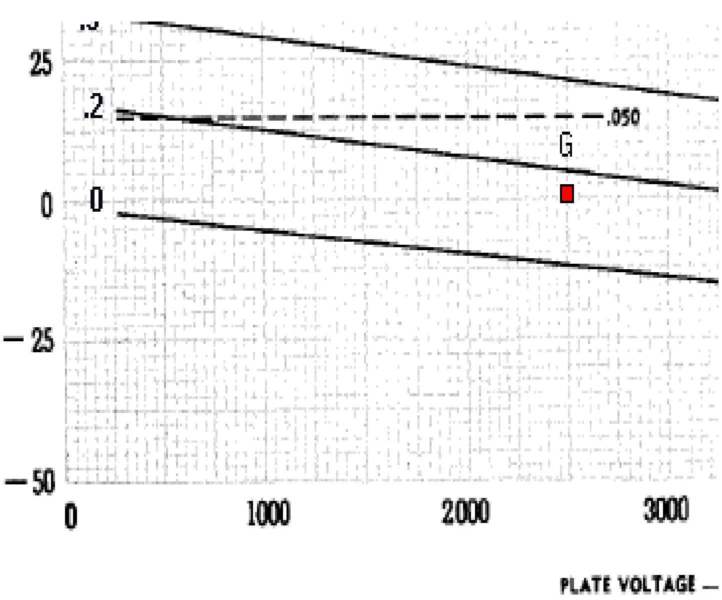
If you have to find your own tube curves, they must be put into a *.bmp file. There are a number of photo processing or graphics programs that will allow you to do this.   If you have only the paper copy, the first step is to scan the curves into the computer. About 300 dpi resolution is a good place to start. You can adjust that later to make the final file fit in the window provided in the program. If too small, it may be hard to read the values off the curves. If too large, you will have to drag the file frequently to get to the needed parts of the graphic, or use the expanded display. If the bmp file is gray scale, the program will not be able to draw operating lines and dots in color, but the files can still be used.

If you have a digital copy in some other format, you can convert it directly with some image processing software. In other cases, display the curves in any program, including a web page, and then you can do an Alt-Print Screen which will copy the screen image to the clip board. Then, paste this into image processing software and save in the BMP format. Before saving some curves you may wish to re-label the plate current curves by putting numbers near the left end of the individual curves. Some published curves label the individual lines only on the extreme right end of the curves and these labels may not be visible without constantly dragging the image back and forth. Some labels are also not very legible, so you may wish to add more readable labels, perhaps in contrasting colors.

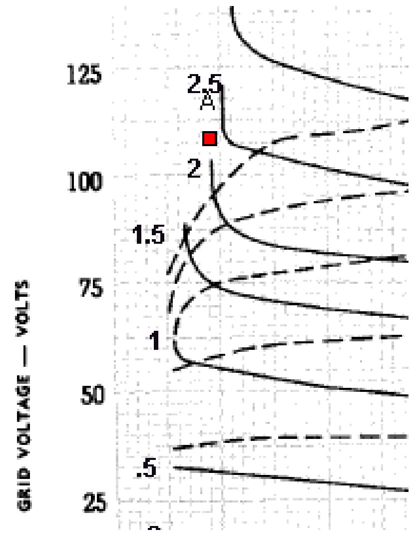
Using the curves for analysis:

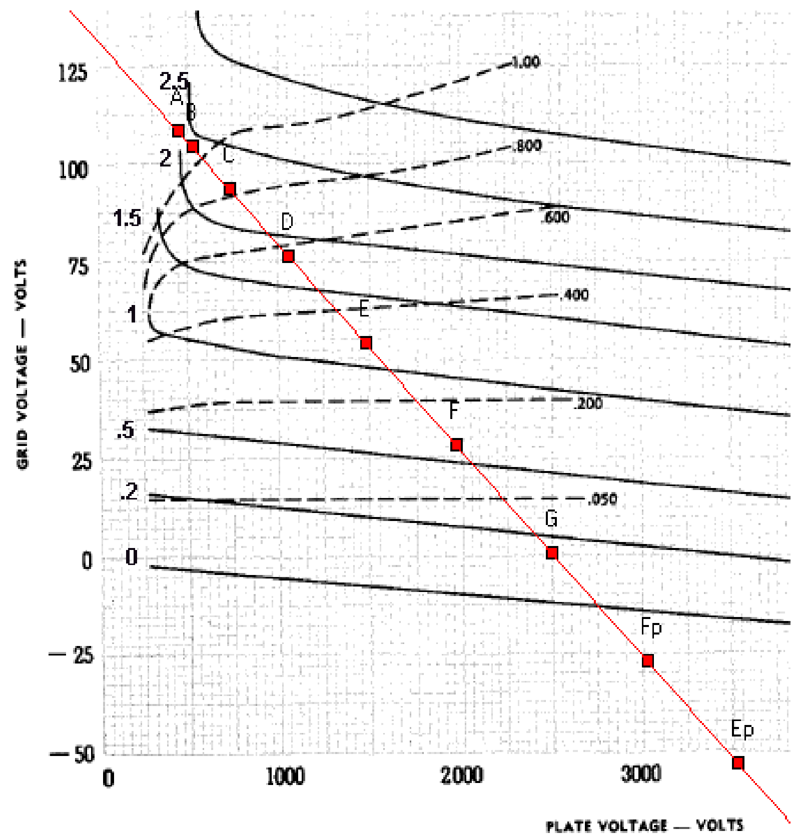
Using the button labeled Bmp, select the tube curves to be used and they will be inserted in the left pane. If they do not appear, hit the Toggle button. You will be asked if the curves are constant current or Ib/Eb type.

For either type of curves, the first step is to define the bias (no signal) conditions. Select a bias voltage that will give you the desired resting plate current with a given plate voltage. For Class C, this will be enough bias to more than cut off the tube. For Class B, the resting bias will be just at the point where current begins to flow. For Class AB, the resting bias will be between 5% and 50% of the current expected under full power output, but should be low enough so that the tube will not overheat, since in the resting condition, efficiency is zero. That is; all the input power goes into plate dissipation. For Class A, the bias point will be such that the resting plate current is about ½ of the peak plate current value. This point will be represented by the letter G on the tube curves. This is drawn by right clicking at the proper point on the graph and selecting "insert point G". Here is an example for a "zero bias" triode. The grid volts are zero and the plate volts are 2500.   The resting dissipation will be under 500 watts, which is acceptable for this tube, a 3-1000Z.



The second step is to select the peak grid RF condition. This will be a point where the grid voltage is at a maximum positive value, and the instantaneous plate current is about 4 times what you want the DC plate current to be. This would be for class C. Use about 3 times for class B. For Class A, peak current should be about double the resting value. This maximum point will be close to the point at which the plate curves start to turn abruptly upwards. For a tetrode, the minimum value of plate voltage at this point will be just a bit more than the screen voltage. Right click here and select "insert point A." The exact location of this point is one of the more important parts of the whole process. Trying different points will give a lot of insight into various ways to operate a given tube. Point A defines the Eg1(max) and Ep(min) parameters.





If you are using constant current (CC) curves, draw the operating line by right clicking again and selecting "draw operating line". This will appear as shown at right. Then, be sure to enter the bias, Ep, Eg1(max) and Ep(min) into the top four yellow boxes. These will be used later for calculations.

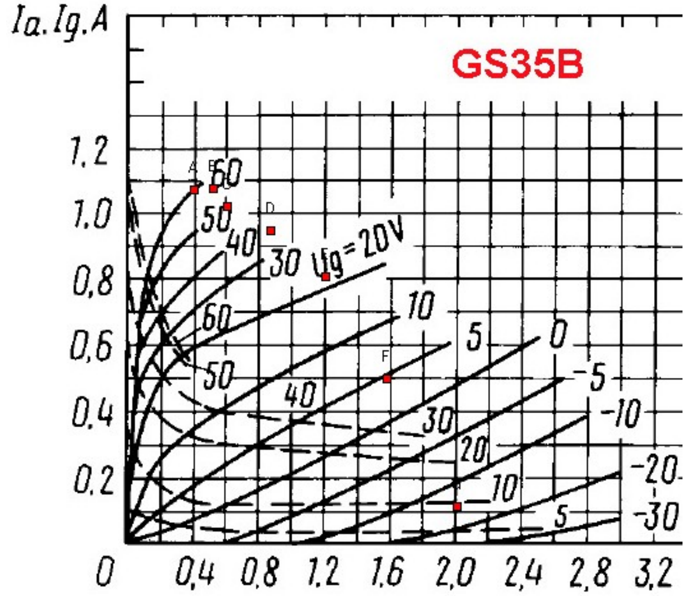
Note that some tube curves are available especially for grounded grid operation. If you are using grounded grid, these curves will give a more accurate result. However, if they are not available, using the normal curves will still give acceptable results when using grounded grid. This is because the main difference in the curves is that the plate voltage is defined as plate to grid, rather than plate to cathode. Since the grid voltage is almost always a small fraction of the plate voltage, this introduces only a slight difference in the final result. Curves for grounded grid operation plot the cathode to grid voltage on the left, instead of grid to cathode. These curves look almost like the other type, but the polarity of the grid is reversed, with negative values being higher on the scale than positive values. Since the program plots grid to cathode volts, not cathode to grid, be careful to reverse the sign of the grid voltage when entering values into the boxes.

When entering the grid bias, you should always include the polarity, when negative. That is, when the grid voltage is negative always include the – sign when entering the data. Also be sure to get the units right when entering plate volts. 5 KV on the plate must be entered as 5000, not as 5. All 4 values to be entered at this point are in VOLTS.

If you are using the Ep/Ip curves, you must follow a different procedure. You will not be able to use the command “draw operating line”. Instead, enter the selected values of bias, Max Ep, Eg1(max) and Ep(min) into the yellow boxes at the top of the calculator and push “Calculate”. Then, enter all the points A, B, C, etc. manually as outlined below.

Bias	EP	Eg1(max)	Ep(min)	Calculate
-15	2000	60	400	

Angle	Ig1	Ig2	Ip	Plate volts	Grid volts
A (180)	0	0	0	400	60
B (165)	0	0	0	454	57.4
C (150)	0	0	0	614	50
D (135)	0	0	0	868	38
E (120)	0	0	0	1200	22.5
F (105)	0	0	0	1585	4.41
G (090)	0	0	0	2000	-15



Inserting points for Ip/Ep curves :

If no constant current curves are available for a desired tube type, you will be forced to use this more tedious method. Using the calculated values of plate and grid voltage for points A, B, etc. find those points on the graph and insert points using CTRL-Left click. For example, for point A, look at the calculated values of plate volts and grid volts that are horizontally across from point A. Using those values, find on the curves the grid volts and plate volts that correspond. You will likely have to interpolate between the grid volt lines as shown here. Place the dot there using the CTRL-Left click, and the point will be named A. Continue to independently place each dot B, C, etc. at the appropriate place. It is this step which is more complicated with the Ip/Ep curves, but once done, the rest is the same as with the CC curves. These dots will generally not be in a straight line. If you get out of sequence and need to replace any dot, click on that letter in the data table. Or use the right click and “insert independent dot”. This is explained at the bottom of the graph when using the Ip/Ep curves.

Ip/Ep curves treat the grid and screen currents in two different ways. Some data sheets include the grid current on the same graph as the plate current curves. However, a different set of grid voltages must be used. This means redoing all of the dots (A-G, etc) on the grid voltage curves that correspond to the grid currents. These will each fall directly below the dots used for the plate current curves. You can manually insert extra dots and call them by any letter you wish, such as Ag, Bg, etc. Other tubes supply a different graph for the grid currents, but the procedure is similar.

Reading current values:

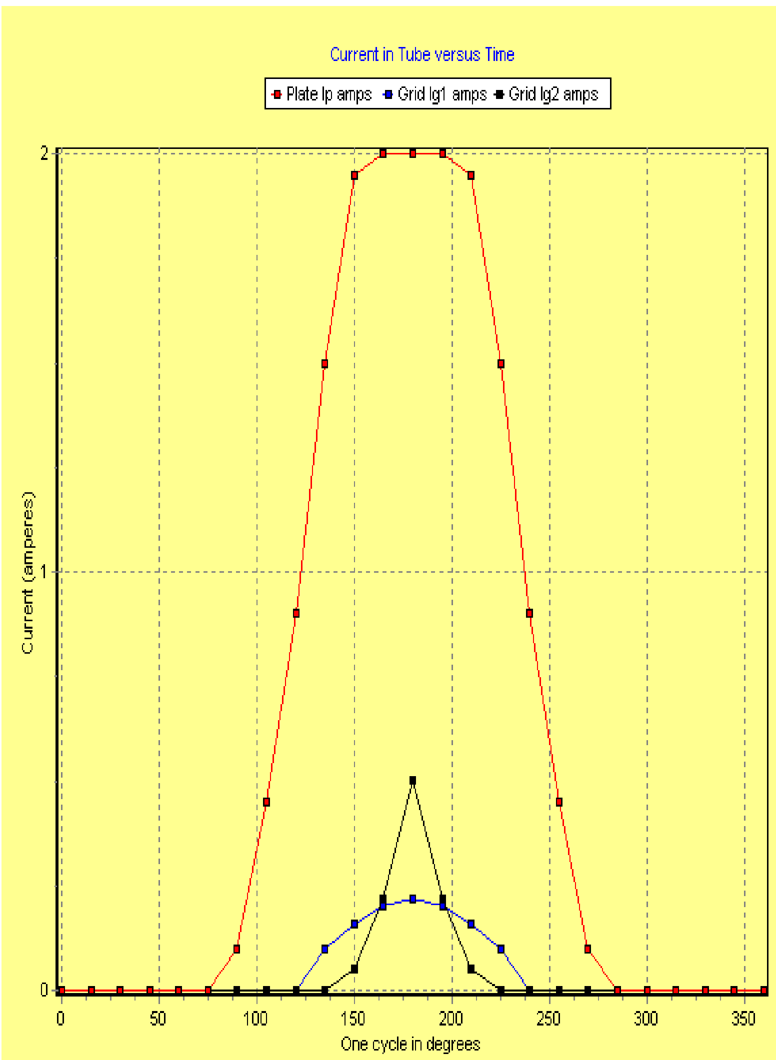
Once the dots are in place, using either the CC or Ip/Ep curves, look at each dot and add the data in the yellow boxes which correspond to the values of grid, screen and plate current in AMPS at each point. Depending on the class of operation, many of the boxes will contain a zero. Only class A operation will have data in all Ip boxes. Many of the screen and grid boxes will always be zero, but are provided for completeness.

Once all of the non zero values for Ig1, Ip and Ig2 have been entered, hit the calculate button and all of the important operation parameters for the tube will be calculated. The Ip values are the most important for getting the tube to do what you want, so you may want to do just those first and then hit calculate. If the output power or plate current is not what you want, re-do the points to get that right first. Then add the screen and grid currents. You can change any value of current at any time and hit calculate. Parameters relevant to that data will recalculate. For a triode, of course, the screen current will be zero.

Parameter	Result
Grid Current (mA)	95.8
Screen Current (mA)	0.00
Plate Current (A)	0.773
Input Power (Watts)	1350
Output Power (Watts)	938
Plate Dissipation (W)	413
Plate Load (Ohms)	1120
Efficiency (%)	69.5
Grid Swing (Volts)	100.0
Resting Dissipation (W)	35.0
Drive power (Watts)	9.58

Circuit Configuration

- (•) Grounded Cathode
- ( ) Grounded Grid



Toggle between the tube curves and the plot at left. This plot shows all of the currents in the tube as a function of time for one complete cycle. These curves should be reasonably smooth. If you have made a gross error in entering the current data, it should be evident from this curve.

Examine all of the parameters at the left of the program screen. If the parameters are satisfactory, the design is done. If not; for example, if the plate dissipation is too high, erase the operating data and try a new set of operating points.

The location of the points A and G are the main design choices. Moving these points as follows will have the following effects:

Point A:

Move up to increase power output, this also increases grid current.
Move down does the opposite. Efficiency is unchanged.

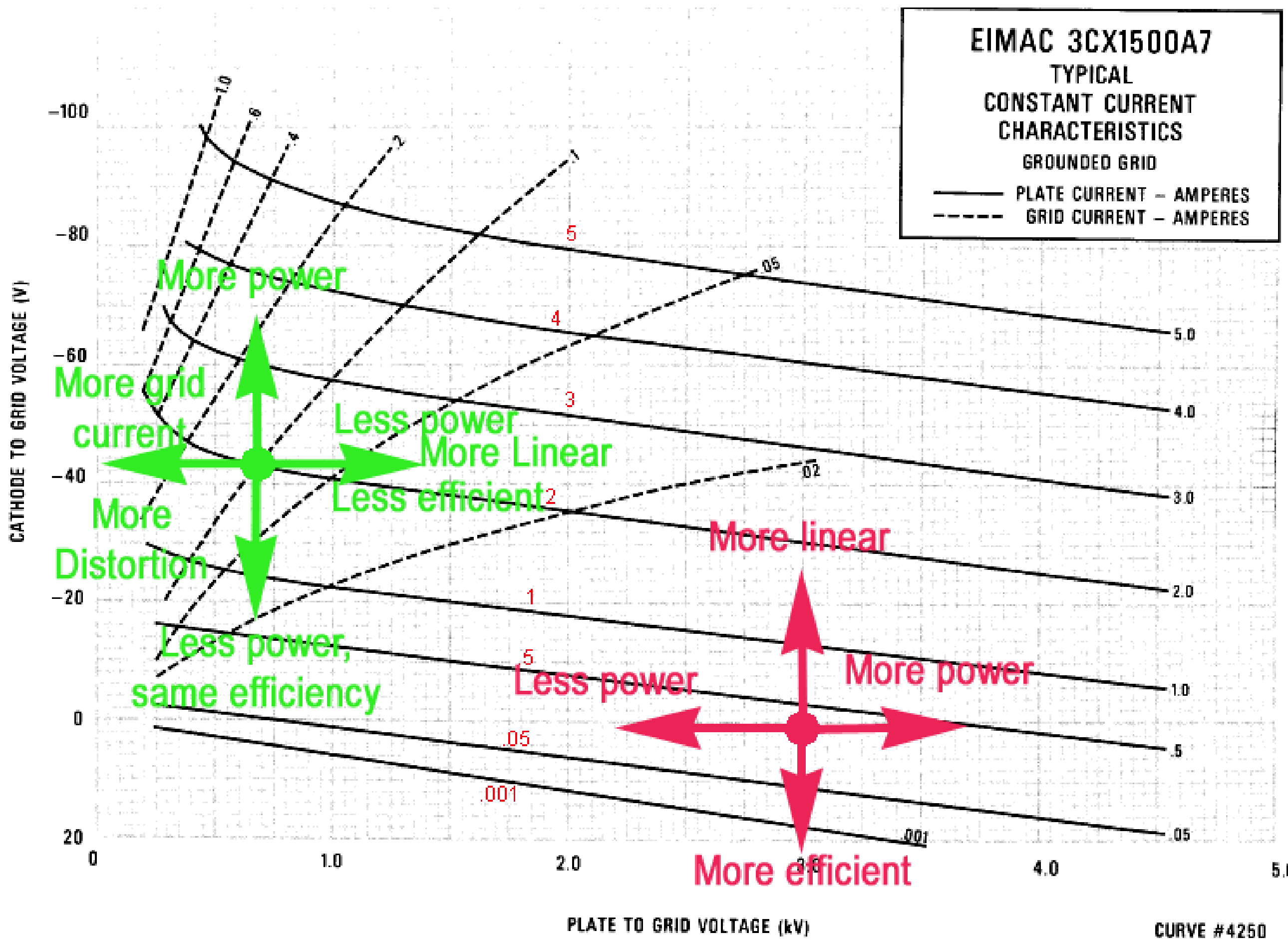
Moving left increases distortion and power output. Moving right does the opposite.

Point G:

Moving up decreases distortion and efficiency, but increases dissipation especially with no drive. Moving down has the opposite effects.

Moving right increases power output and efficiency, but is limited by maximum plate voltage rating. Moving left has the opposite effect.

The effects of moving points A and G are illustrated below.



Now, or at any time, you can check the Grounded Cathode or Grounded Grid option. You will note that the output parameters are unchanged, but the input parameters will change significantly. Note that for GG, a portion of the input power will be added to the output power. Of course, for GG operation considerably more drive power is required. The calculated output power does not include this “pass through power” in the total. Sometimes, tube curves are plotted especially for GG operation, instead of GK operation. Either type of curves can be used for GG operation, but the GG specific curves may be slightly more accurate for analysis of GG operation.

Be aware that this program does not consider losses in either the output tank circuit nor the input circuit. Losses in these will reduce the actual output by a few percent and may require considerably more input power than the value indicated. This loss will increase as the frequency of operation goes higher.   Because of these losses, the absolute values of output power and efficiency may not be achieved in practice.

Also be aware that the curves represent average operation of the tube type in new condition. Even new tubes may vary from the average values, and depending on their age and condition, may differ by quite a bit. The relative values of all parameters should be much more accurate as you make changes in such things as plate voltage, plate current, plate loading etc.

The results of your work can be saved by using the save button and giving the example a name. This can be recalled later for further work or checking. There are several saved examples. Please note that these examples may not represent a suitable way to operate the tube shown. They are given to show the use of the program, not necessarily a recommended use of the tube itself. Where the operation seems to be unsatisfactory, try changing the operating parameters and see if you can get a better operation.

Read the Eimac Tube Performance Computer document for fuller understanding of the method. That document describes the graphical method which was devised by E. L. Chaffee in 1936 and used for many years and from which this computer aided method is derived. Further examples can be found in the "Care and Feeding of Power Grid Tubes" also by Eimac.   Both of these very valuable documents can be downloaded free of charge from   http://www.cpii.com/library.cfm/9

I will be glad to answer any questions about the use of this program. You can contact me at:
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K4ERO – June 2009