THE 6146B STORY U2

The following information should help to decide for yourself what to believe regarding the proper selection, use, and expectations for the 6146 series tube.

The first 6146 was designed by RCA and made its debut in the early 50's when class C and AM were the most popular modes of service. Several years later, in the late 50s, the growing interest in SSB and linear services found the 6146 to be a good candidate for class AB1 linear service, but it had limitations.

Please refer to the 1952 RCA 6146 tube data sheet "Plate characteristics chart"; with the plate at 150V, screen 200V, and the CG at zero(0) Volts, the plate current is .410A which is the peak limit using AB1 service. Is the .410A number fixed or even close from tube to tube? No, it could vary from approximately .300A to .550A from tube to tube.

Class AB1 service prohibits current flow in the CG, limiting the CG to =< zero Volts. The original 6146 (1952), like most Beam tetrodes, has an approximate 2 to 1 variation in plate current with the same grid voltage applied. One tube could be carrying 1X and another 2X times the current using the **same CG voltage**. This ratio can be found in the 1952 6146 data sheet "Characteristics Range Of Values For Equipment Design" under Plate current and note #3; "With the heater 5.5volts AC, Plate 300 volts, Screen 200 volts, and control grid -33 volts, the plate current can vary from 45mA to 85mA". This is a ratio of 1:1.84, and It must be noted the heater voltage is at the marginal low limit. The ratio for All of the follow-on tubes will be 46mA to 94mA, 2:1

The reason for the 2:1 variation:

The 2:1 plate current ratio in Beam type tetrodes is a result of variations in the lateral alignment of the CG and SG during manufacturing. You can view a pair of photos of the internals of a 6146 to get a flavor as to how precise the CG and SG must be aligned, there are two photos.
http://www.k9axn.com/_mgxroot/page_10887.html

Visualize this: You're on the cathode looking toward the plate; you see the CG but cannot see the SG because it's behind and in the shadow of the CG. Now, You're on the plate looking toward the cathode, you see only the SG because the CG is behind and in the shadow of the SG; Perfectly aligned The CG will have maximum current control (Bias will be lowest) and the P to CG capacity will be the lowest.

Another variation to note, the distance from cathode to control grid will contribute to the range variations in two ways. If the CG is moved away from the cathode, the gain will be reduced and the Cathode to CG capacity will disturb the balance of the Plate --- CG --- Cathode bridge requiring more neutralizing feedback to stabilize the tube. This results in what appears to be variations in P to CG capacity, but is simply bridge distortion.

The width of the range above clearly explains why the tube data sheets state, “When using two or more tubes in parallel, matched tubes should be used”.

If you choose to use mismatched tubes, the following techniques should be considered. The most common method used is to install separate grid bias pots to individually adjust the idling plate current, simulating a match. Careful, one tube at the low end and one at the high end of the range will now be sharing the load equally at idle grid bias with the bias voltage much lower on one than the other. This solution unravels a bit when AC drive is applied the tubes. The control grid in the tube with the lowest idle bias will be driven to zero Volts much earlier than the high bias tube. This causes the AALC to engage, limiting the power out to that of two low output tubes. This gives the false impression that the tubes are soft.

A third and more eloquent solution is to install a differential balancing pot on the screen grids to adjust the screen voltages for a match using the **same** grid bias. They will be more linear throughout the conduction range.

All was good until the late 50’s when a universal effort by all tube builders to tighten the ranges found in the (Characteristic Range Of Values) guaranteeing the tube with the lowest bias range could deliver a level of power that could reach the specified plate dissipation **while running AB1 mode**. From the 1952 RCA 6146 data sheet, the plate characteristics chart defined typical characteristics to be .410A when the CG is at zero volts, screen 200V, and the plate 100V. These are typical for the Bogy 6146 but we know the plate current can vary widely from tube to tube with the same CG voltage applied.

A minimum plate current was established for the future 6146 family that was to be called “Controlled zero bias”. It defined the **minimum** plate current with the plate 100V, screen 200V, and control grid 0V to be .330A and was specifically an enhancement to support class AB1 service. With a peak current of .330A and 750 Volts DC applied, the tube could deliver 53 Watts out with 78 Watts in for 25 Watts of plate dissipation. This was coined "Controlled zero bias" by RCA in the 1963 6146A doc.

If you need help to understand the data sheets or objectives of the calculations to determine output, load impedance or load line please send a note.

Think about this as you read the timeline details: The (1952) RCA 6146 was the genesis of the 6146 family. Nothing was done by RCA to enhance the 6146 until the release of the Sylvania 6146A in 1961. Then, fifteen months later in 1963, RCA released the improved RCA 6146 and three months later in 1963 RCA released their 6146A.

Beginning with the Sylvania 6146A in 1961 all three tubes (The 1961 Sylvania 6146A, the 1963 RCA 6146, and the 1963 RCA 6146A all had the same P to CG capacity .24pF and typical operation specifications as a class C amplifier up to 60MHz. The original RCA 6146 (1952) specifications were totally different from any of the follow on 6146 tubes. The improved RCA 6146 (1963) and RCA 6146A are apparently partial copies of the (1961) Sylvania 6146A which came to market 18 months earlier.

The original RCA 6146 is a very different from any of the follow-on 6146 series tubes. Note the 6146 plate characteristics charts. You will see a significant knee at 750mA for the 1952 RCA 6146. Now, note the same chart for any of the follow-on tubes beginning with the Sylvania 6146A 1961 and improved RCA 6146 1963. The plate can be driven to 900mA with no appearance of a knee or resultant distortion. There is some evidence that Sylvania had corrected the Knee problem in their original 6146, circa 1957 or 1958 because the P to G capacity was .24pF and the characteristics match their 6146A except for the dark filament.

The knee problem with the original RCA 6146 from 1952 was corrected in the first Sylvania 6146 prior to their 6146A in 1961. What changed? In a beam tetrode the plate is positioned further from the screen than the pentode allowing space for the formation of a virtual cathode (An electron cloud) to replace the suppressor grid. During the conduction cycle of the original RCA 6146 the current increases to 750mA and the plate voltage drops to 150 volts precipitating a sharp drop in plate current and a sharp almost vertical increase in screen current. The virtual cathode has been overwhelmed.

Compare plate and screen curves for the RCA 1952 6146 with their new 1963 6146; they are far different tubes. They apparently increased the space between the plate and screen.

TIMELINE DETAILS:

1961 SYLVANIA INTRODUCES THE 6146A

The first shot across the bow was the introduction of the Sylvania 6146A in August of 1961; 18 months **before** the RCA 6146A. There were three notable improvements in the Sylvania 6146A; the cathode, plate, and tightening the tube parameters.

THE CATHODE:

1. The cathode was built using the same concepts as used in their industrial or Gold Brand tubes. The heater was made using **Rhenium-Tungsten wire** which is more ductile and displays <u>higher resistance than pure Tungsten</u>. The diameter of the Rhenium Tungsten filament was increased to compensate for the added resistance in order to match the 1.25A filament design point of the RCA 6146. The larger diameter and ductile properties would significantly increase the life of the filament because It was less fragile to expansion and contraction from heat variations.
2. A **dark coating** was applied over the oxide insulator on the filament which improved the heat transfer from heater to cathode sleeve.
3. The cathode sleeve was cold rolled powdered metal producing a textured property that would bind with the emissive material to prevent peeling.
4. A mixture of emissive materials was applied to the cathode sleeve with each being individually and progressively activated extending the life of the tube.

THE PLATE:

The plate was a new design beginning with the Sylvania 6146A. They had developed a process to laminate Copper, Steel, Nickle, and Aluminum. The Sylvania 6146A (1961) used a <u>**thin laminate**</u> of Copper in the composition of the plate. The copper could more rapidly disburse heat away from the target area or hot spot, to a wider area of the plate to be dispatched. The total area of the plate was the same in all 6146 models but the introduction of copper in the plate laminate essentially increased the plate dissipation. Note: The increased plate dissipation was not detailed in the data sheet. It was simply called an increased safety factor. I don't have photos of the Sylvania 6146A, but here are a pair of the RCA and Sylvania plates with 40 Watts of dissipation for the RCA and 45 Watts for the Sylvania 6146B. Note the wider distribution for the Sylvania and narrow band for the RCA tube.

http://k9axn.com/attachments/6146B_LOF_40W.JPG

http://k9axn.com/attachments/Sylvania_6146B1_45w_Infrared.JPG

TIGHTENING THE TUBE PARAMETERS:

P to CG capacity of the 6146A was .24pf and a new base with additional shielding was implemented.

Also, the tube with the lowest AB1 plate current with the grid at zero volts will have a higher current than the tube with the lowest AB1 plate current in the RCA 6146. This change will later be called "Controlled Zero Bias" by RCA in their 6146A tube. Controlled Zero bias simply guarantees no less than 330Ma of plate current at zero Volts on the CG when using class AB1 services.

1963 RCA RESPONDS WITH AN IMPROVED 6146

RCA's response to the Sylvania 6146A was to introduce an improved 6146 in January of 1963. I don't recall ever reading an advertisement from RCA regarding the new 6146. Interestingly the plate to grid capacity was increased from .22pf to .24pf and the input capacity reduced from 13.5pf to 13.0pf. No improvements to the cathode or plate were made. However, tube parameters appear to have been changed to improve performance in AB1 service including "Controlled Zero Bias" and to correct the knee problem in the 1952 RCA 6146. This tube was the prototype for the RCA 6146A that would follow in May. This was called "Controlled zero bias plate current" by RCA in 1963, but evidence suggests it was included in the 1961 Sylvania 6146A design which targeted AB1 service.

1963 RCA --- FOUR MONTHS LATER, INTRODUCED THEIR 6146A

This tube is the same tube as the improved 6146 introduced three months earlier adding the dark cathode and improved base and shielding.

THE CATHODE:

They used the original Tungsten 1.25A filament with a dark coating applied over the oxide coating of the filament to more efficiently transfer heat to the cathode sleeve which would be touted as the "Dark Cathode" which Sylvania had used earlier in their 6146A in 1961.

THE PLATE:

Was unchanged and no copper lamination.

PERFORMANCE IMPROVEMENTS:

Tightened parameters, the same improvements as their 1963 6146 including Controlled Zero Bias".

1963 OR 1964 SYLVANIA INTRODUCED THE 6146B

I believe in 1963 or 1964 Sylvania released the 6146B but have not found evidence to support the certainty of the date. Their 1964 tube substitution guide and data sheets suggest the replacement of the 6146A with their 6146B.

THE CATHODE:

The Sylvania 6146B used the same cathode as their 6146A above, again, using slightly larger diameter filament wire to accommodate the higher resistance of the new Rhenium Tungsten wire to equal the resistance of the 6146 so they would be truly unilaterally compatible with the 6146; The filament current in the Sylvania 6146B is 1.25A, the same as the 6146.

THE PLATE:

The Sylvania 6146B used a **much thicker Copper laminate than their 6146A,** further increasing the rate of heat distribution away from the target (Hot spot) area of the plate. This essentially used more of the plate area to disburse heat.

The bulb, (Hot spot temperature) of the Sylvania 6146 and 6146A tubes were listed as 220C and the Sylvania 6146B unlisted; assuming it remained 220C:

1964 RCA INTRODUCES THEIR 6146B

THE CATHODE:

The filament in the Cathode was changed to Rhenium Tungsten using the same diameter wire as the original filament; increasing the resistance and reducing the current from 1.25A to 1.125A.

RCA suggests their 6146B is unilaterally compatible with the 6146 or 6146A. THIS IS AN ABSURD STATEMENT! I believe Glen K9STH wrote that RCA had rescinded the statement and he was correct. Many top of the line radios, series connect the 6146X filaments. Try the following:

Series couple an RCA 6146B and a 6146 or 6146A filament, power them up and check the filament voltage on both. The results will explain why the 6146B fails not the 6146. Don't calculate it, do it. The filaments will start from cold at 2 ohms and increase to approximately 5 Ohms when hot. The highest voltage will occur on the 6146B and the lowest on the 6146. As they heat, the resistance in the 6146B will increase more rapidly than the 6146. The 6146 will never reach its operating temperature with the resistance failing to increase with heat, the 6146B will see an even higher voltage. The higher voltage/current on the 6146B will increase the temperature and resistance of the filament causing the 6146 to cool and resistance to diminish. This cycle continues until the voltage across the 6146 is approximately 5.2V and 6146B 7.1 V. This stops just short of the 6146B carrying the full load of both.

This explains the numerous reports of the 6146B failing when attempting to mix tubes. The failure usually appears to be the screen failing from overheat and shorting --- the fireworks. There are other reasons.

THE PLATE:

The plate appears to have remained the same as the 6146; no copper content and the area and thickness are the same. The only change was their acceptable increase in bulb temperature from 220C to 260C degrees. How many tubes have you found to suggest 260C for a bulb temp? The increase in power was simply a result of increasing the screen voltage and allowing the plate to operate 40C higher at 260C. If you have evidence that there were other changes please copy me.

THE INIGMATIC S2001A:

I simply don't know what year it was first introduced. I know that it was used very successfully in the TS830 and others. The only information that I have is grey matter and a handwritten notes from dog and ponies decades ago and significant testing. If anyone has archived information please add it to this conversation.

The S2001A was essentially a copy of the Sylvania 6146B with some enhancements.

THE CATHODE:

The cathode was a copy of the Sylvania 6146B using the Rhenium-Tungsten filament wire but with the same diameter as the Tungsten filament. The filament current is 1.125A which renders it incompatible with other 6146's for the same reason as the RCA 6146B. Note: The filament current, 6.125A, was their statement but was found to be 6.05A. This rendered it to be unilaterally incompatible with any of the 6146 family.

THE PLATE:

The plate was much the same as the Sylvania model albeit an even thicker copper laminate. This enabled the dissipation rate to be further increased.

THE BULB:

The thickness of the glass was increased from .035" to .050" and appears to have been treated with the same anti reflective material as found in eye glasses or some composition that has the same effect.

Please view the photos of the various tubes under power at

http://k9axn.com/_mgxroot/page_10933.html

These were shot with lights on and lights off to visualize the infrared profile with key down for 20 minutes at the defined DC power levels. Note the reflections seen with lights on, it will be obvious that the S2001A has much less reflection than the other tubes. Note the plates in the Matsushita and Sylvania tubes using copper laminate plates viewed with the lights off show the heat distributed away from the target area far more efficiently than the RCA models.

UNIQUE CHANGES:

The beam deflector plates had cooling windows to help cool the grid posts much the same as the Industrial 6146 and Sweep tubes.

CONCLUSIONS:

1. The RCA 6146B is not unilaterally compatible with the RCA 6146 or 6146A!
   The S2001A is not compatible with any of the 6146 family!
   The Sylvania 6146B is unilaterally compatible with the RCA 6146 or 6146A.

2. RCA did not use copper laminate in any of the 6146 family. Simply increased the acceptable bulb temperature from 220C to 260C and increased the screen voltage to increase the power out.

3. The data sheet for the RCA 6146B, “Characteristic range values” Note 3 , sub note 3 refers to the controlled zero bias enhancement for AB1 service. Pay special attention to the filament voltage. It is 6.75 volts. The 6146A needs only 6.3V on the filament for the same results. The filament current in the RCA 6146B is 1.125A and the 6146A 1.250A. It is clear, the RCA 6146B having used the same diameter Rhenium Tungsten wire for the filament as the original was a mistake. The filament in the 6146A and others appear to have a higher emission rate than the RCA 6146B.

4. The notion that you don’t need to use matched tubes in your transceiver is rooted in the statement in the Kenwood radio manuals e.g. the TS-820,and TS830 that use the S2001A Matsushita tube. It is a reasonable statement when using the Matsushita S2001A or Sylvania 6146B tubes in a transceiver that is designed to use two stage feedbacked for the following reasons.
   First: The use of a heavy copper laminate in the plate of the S2001A increases the plate dissipation to approximately 45+ watts. Sylvania states their 6146B copper laminate adds a 25% safety factor for plate dissipation.

The S2001A and Sylvania 6146B have more than adequate plate dissipation to tolerate mismatched tubes; the RCA 6146B does not. Second: The loss of linearity due to using mismatched tubes in the TS-830 is compensated for, by the 10db improvement in IMD attributable to the **two-stage feedback design copied from the Collins KWM and 32S series radios.** Radios that use the single stage feedback design providing negative feedback from the plate to grid capacity can achieve only 3db to 4db of IMD improvement when using the 6146. Suggesting the use of unmatched tubes other than the S2001A or Sylvania 6146B in the Kenwood and other transceivers that implement two stage feedback design is inappropriate! Using the Kenwood statement to suggest the use of unmatched tubes in any linear amplifier is nonsense. If you're speaking to a class C amplifier, different story. They care much less about neutralization because they are naturally swamped more heavily and don't care much about linearity. This explains the statements by the folks that use the vintage class C or AM radios: "Never had a problem using any 6146 combination" ---- as long as the filaments are not series connected.

5. Were there conspiracies? Conspiracy is a subjective word depending on your mood. Did your neighbors pooch wet your jamas thinking you were a new sort of fire plug, did someone turn the hot water on somewhere while you were in the shower, or why did junior leave his roller skates in the hall at the head of the stair case. Nah, it's simply the competitive nature of the human spirit and coincidence. Inaccuracies in the tube data sheets may have been deliberate or misleading, you decide. The P to CG capacity in the 6146B data sheet claims to be .22pf --- down from .24pf. Interestingly we know that statistically you will need to use more feedback to neutralize your amp when replacing a pre-1963 RCA 6146 with the RCA 6146B. The Sylvania 6146B data sheet claims the filament current is 1.125A: Not so, it's 1.250A same as the 6146.

There is one common thread in the story. The curve charts for the original RCA 6146 are very different from all the follow on 6146 family tubes. There is substantial evidence that the Sylvania 6146 was the genesis of all the follow-on 6146 tubes. Last, I know of no other 6146 vendors other than

Sylvania or Matsushita that used copper laminate in the plates.

Hope you find this information useful and it substantially supports the statistical paper written by Glen Zook K9STH

If you have additional information please feel free to send it to me and I will add it and acknowledge your contribution.

Regards Jim K9AXN