10.5.11 Match Point

Amplifier tubes run through a multi-stage manufacturing process that does not tolerate any major errors. If a process step does not go according to plan, the tube parameters deviate from the values given in the datasheets. The manufacturers (and some retailers, too) therefore test all manufactured tubes, and weeds out the sub-par specimen. The remaining "good ones" are ennobled with the attribute "selected" and sold to the consumer. However, rumor has it that there were some singular cases in which deficient tubes have found their way to the musician. For this reason, the consumers of the "hot goods" from time to time stage a match in which the "matched tubes" have to compete against each other: comparison tests. These typically are a merry ado, extensively covered in the trade magazines. *Translator's note: From the point of view of the scientist and engineer, these reports often have a rather special "quality" bordering on the dysfunctional. That, however, does not seem to bother the testers nor many of the readers even if the process is repeated in the exact same way – in fact the contrary appears to be the case. Is this testimony to the "magic of the tube"?*

10.5.11.1 Selecting and Matching

Translator's note: I choose not to translate the 1st paragraph here because it is a send-off targeting the often excessive use of English terms in German music trade-magazines. Corresponding German terms would be available, so often English is brought in just to sound cool, or to hide a lack of proper understanding of the subject matter behind impressive English terminology. A translation of this paragraph would therefore almost by definition not work in English. Having said that, isn't a term like "transconductance" just marvelously sexy and seductive if we write about guitar amps? Anyone talking about guitar technology should put "transconductance" to good use in any conversation. Seriously though, "transconductance" is a parameter that tubes are "matched" by – so let's get back to our book …:

Both chemistry and mechanics are involved in the manufacture of tubes, and in both areas, technical tolerances exist. The cathode coating, the metals of the electrodes, the wound grid-wires, the getter, the insulators, the vacuum – varying parameters wherever we look, and therefore all tubes differ in their operational behavior. The really bad ones get to be thrown away, but the parameters of the useable tubes are still subject to scatter. Consequently, they are individually measured ('selected'), and for use in power stages they are paired up ('matched'). It is customary to operate the power tubes in the typical operating point ('at idle') and to specify the plate-current (PC) flowing at a manufacturer-specific supply voltage (e.g. PC = 41 mA). Usually, the supply voltage is not indicated but this is not that necessary if it is typical for the amp (and consistent). It is, however, not sufficient that two tube characteristics coincide in a single point since the tube is subject to a drive signal, and both voltage and current will change accordingly. It is therefore purposeful to check also the dynamic behavior – on top of the static behavior. Enter the transconductance. Barkhausen [Lit.] put his tube-formula together using it: durchgriff (see Chapter 10.5.1) x internal impedance x transconductance = 1. The **transconductance** indicates how strongly the plate-current changes with variations of (only) the grid-voltage. Since the $I_a(U_g)$-correspondence is non-linear, the transconductance can only be determined (as differential quotient) for small drive levels: $S = dI_a / dU_g$, for constant U_a. The information of e.g. S = 5 mA/V consequently expresses that plate-current changes by 5 mA if the grid-voltage is changed by 1 V. In this scenario, the plate-voltage must not change i.e. the load impedance must be zero – therefore the more extensive, alternate term would be **short-circuit-transconductance**.

Two straight lines are identical if they share one point *and* have the same slope. If characteristics of tubes were straight lines it would be sufficient to measure one point (PC = plate current) and the slope (S = transconductance). However, tube characteristics are not straight lines and therefore two tubes that have been 'matched' via *one* PC- and *one* S-value may very well differ. **Fig. 10.5.38** shows corresponding measurement results. The 35-mA-operating-points of the curves shown in the left-hand section correspond, but the plate-currents of these two tubes differ significantly for grid-voltages converging towards zero. The two tubes documented in the right-hand section show – at the 35-mA-operating point – approximately the same transconductance but their bias-voltage differs. The EL84s on the left are specified with a transconductance of 9 mA/V, the EL84's on the right with 10 mA/V – not a big difference. Given such similar 'matching specs', we would not expect curves differing as strongly.

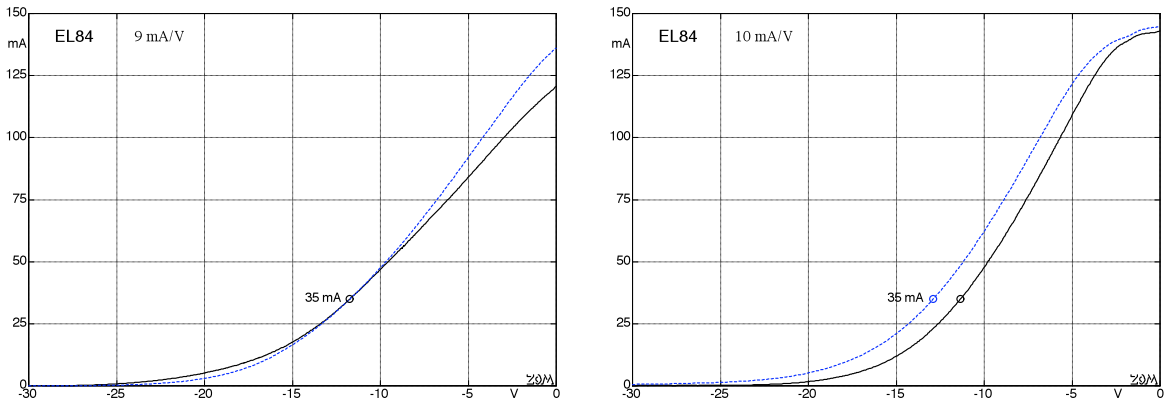

Fig. 10.5.38: EL84-tubes with 'matched' transfer characteristics. $U_B = 350$ V, $U_{g2} = 300$ V, $R_a = 2$ kΩ, $R_{g2} = 0$.

Or maybe we should. Maybe this is why the H&K sales department states: *"for our H&K-amps, we had purchased selected, i.e. matched tubes, but we still experienced a high rejection rate because many tubes did not meet our requirements (Gitarre & Bass 4/09)."* Please note: if you match tubes in only one point of the characteristic, they are not necessarily a match at other points. In practical operation a tube does receive a drive signal, and here not only operating point and transconductance play a role, but among other things also the behavior in the extreme ranges: how well does the tube insulate in reverse operation, how much current will it draw when fully driven, how big is residual voltage caught in the tube. All this should also be tested, shouldn't it? No, not as a rule it isn't – because often there is not even any insight that such measurements would be required. Frequently, the equipment is lacking, too – available is merely your no-name tube-tester indicating "bias" and "transconductance", and that's it: done! To compensate, the plate-current is determined to the tenth of a milliampere, and consequently the PC-values of the 'matched' tubes correspond to the tenth, too. You want to avoid the risk that a musician complains because 36,6/36,7 mA is offered as perfectly matched. Assuming an allowable scatter of the plate-current of ±5 mA, a bin width of 0,1 mA results in 100 different bins. If the transconductance is to be matched with three digits, as well, there might be 100 "transconductance bins". And so the matching person (is he/she a matchmaker, then?) is confronted with 100 x 100 boxes, and bags 'em: every pair matched to a percent. In some cases, this process, tube pairs of astonishing synchronization will go on sale, as shown in the left-hand section of **Fig. 10.5.39**. But then there will also be badly matched ones, like the example given in the right-hand section of the figure. If anyone absolutely is of the opinion that power tubes need to be matched: here you are being served – either way. Incidentally, the two EL34's are, at 43 Euro (per pair), not low-cost but of "excellent quality".

Of course, the transconductance-data printed on the boxes of the measured EL34's correspond to a tenth of a percent: 11.28 mA/V, for both tubes. That may even be correct in some point of the curves – it is, however, unlikely that these tubes were tested at all under full load. And so this "matching" is of little use.

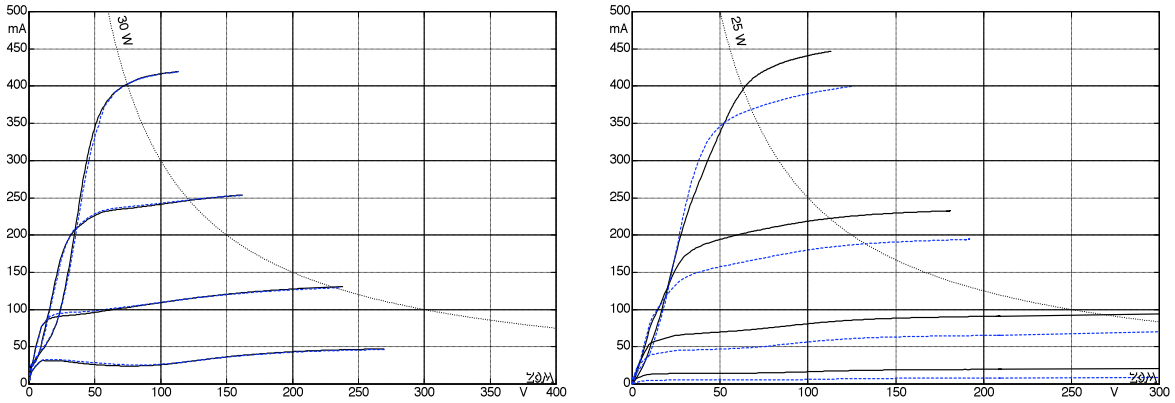

Fig. 10.5.39: Output characteristics of 'matched' tubes. Left: 2x EH-6550, right: 2x EL-34B-STR.

Shelling out e.g. 35 Euro rather than 13 Euro for a pair of EL84's because they are 'selected' and 'matched', it seems only fair to expect not just well matching characteristics but also a correspondence to the curves published in the test certificate. In **Fig. 10.5.40**, we see a comparison between a reference (Philips) and two newly-developed EL-84-STR. According to promo, the latter are supposed to introduce a new standard, and guarantee minimum production scatter. While the idea of a standard may be interpreted this or that way, the fact that the scatter in not minimal in the new tubes is clear enough to be recognized by even the most cloth-eared head-banger. It seems hardly possible for any retailer to more efficiently shoot down his own highly-praised "premium dynamic matching".

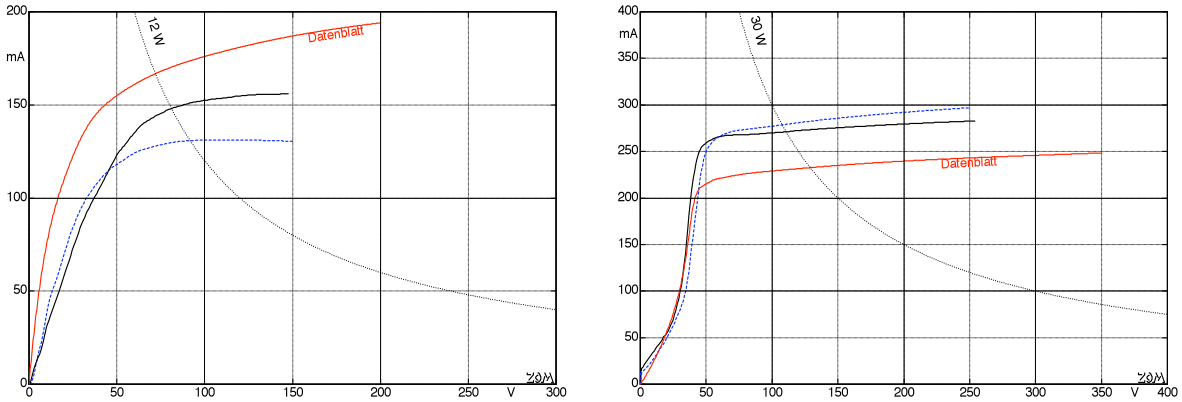

Fig. 10.5.40: Output characteristics (U_{g1} = 0) of two EL-84, 'selected' and 'matched'. Right: 2x JJ-6L6-GC.
("Datenblatt" = datasheet)

The right hand part of the figure shows that it is also possible that datasheet-specs are exceeded: both measured JJ-6L6-GC perform better that they need to. That is gratifying, but the screen grids are under more strain, as well, and the gratification about the high performance will quickly vanish if the tubes fail after a short time. That's the gratification of the musician that's gone, cause the dealer will continue to be gratified as the next duet/quartet/sextet/octet/duodectet needs to be acquired. A hint on the side: why not buy, instead of 12 'matched' tubes, 35 industrial tubes for the same money and check whether they won't do the job just as well, either?

10.5.11.2 Comparison tests

Since the market for tubes is entirely non-transparent, every purchase amounts to a gamble. Good to have the "tube gurus" who give recommendations, or even organize **comparison tests**. Which one is the best tube? In many corresponding test reports, the guitar used is presented with much enthusiasm (*1958 faded vomit green*), as is the involved amplifier (*1962 brown Deluxe with Marcus Hotsteam's Mod No. 17*), and the speaker (*a pair of Pinkywinky-Tubbys, with more than 150 h of running-in by playing Blackmore-licks*) so that everybody realizes that true experts are on the job here. Popular is also to point to the jurors (*even Blind Fat Broonzy had a listen*), and the location of the affair (*we all met in Hamburg*) – possibly because of the specific given air pressure. Then there's some dignified unpacking: 2 pieces 6L6-GA, 2 pieces 6L6-WGB-STR, 2 pieces GE-6L6-WGC-NOS (*loaned 'em from Crack Snootshack's pal*), and many another elitist precious'. Plug 'em in, warm 'em up, listen to 'em. "*Most of us arrived at the opinion that the WGB is a touch louder but doesn't give the oomph of the WGC; some liked the GA better, though. Everybody agreed, however, that somehow the NOS very clearly sounded the tightest."* Man, those tube tests – one could get addicted to them. Really informative, somehow.

Not to be misunderstood: this is (so far) a free country; hey, any minister of finance can tell tall tales about his state bank – so why shouldn't aging guitar-slingers just as well publish a tube test or two? Is it sufficient to use a mere two specimen per tube type? Well, at $ 200 per pair, we get that. It is an irrefutable axiom, that listening tests are imperative – just as the fact that never ever will any measurement data be published. As a rule, the tester will have procured that *"Faded Vomit Green"* easily worth 6 numbers among friends – but there is no adequate instrumentation. And even if that were available, the tester could not be bothered to get an understanding of how inter-modulation distortion and difference-tone distortion is not the same thing. Rather, an impulsive "*forget all that theoretical baloney*" will be included in the test-report – and that will not be entirely off the mark, either. Amplifier tubes are designed to be listened to, not to be measured. However, it is the measurement that allows for elegantly objectifying any differences. As a supplement to the listing test, of course. "*Of course NOT*"? Well, it's a free country (see above).

Such listening tests convey the impression that every type of tube has its own sound-shaping characteristic. Indeed, the sound of an amp can noticeably change as the power tubes are swapped – and so each tube must have its special frequency response, musn't it? It will boost of cut the treble, won't it, or it will amplify the bass with particular force. An analogous conclusion would be: as we feed more air to the Bunsen burner, the flame will become hotter – therefore air is combustible. Well, it ain't – and in just the same way, all tube parameters are frequency-independent throughout the audio range. We should not give highest priority to thermal infrasound effects, nor to MHz-effects. As every electronics-undergraduate learns in the circuit-design course: changing a frequency-independent gain-factor in a system with negative feedback may well change the overall transfer function in a frequency-dependent manner. The same can happen if the internal impedance changes by a frequency-independent factor. The frequency response does depend on the tube, but interactively, specific to the amplifier and speaker. Comparison test for tubes are always flawed in that one never knows how far the results are at all applicable to another amplifier. Moreover, one needs to be afraid of a complete and utter disregard of the basic rules of psychometric test-methodology: the test persons are plain prejudiced because no blind testing is done. Or, the test signals are changed in addition to the tube-changes: someone/anyone plays something/anything on the guitar. Reproducibility? No such luck … dream on!

Everyone in the process of purchasing tubes and banking on general verdicts such as "*for distortion sounds, the Sovtek 5881 WXT was the absolute winner in the test*" should know that the parameters of tubes are subject to scatter (due to the manufacturing process). The left-hand section of **Fig. 10.5.41** shows the output characteristics of 6 6L6GC-tubes made by Ultron. That's only 6 tubes and therefore not enough to indicate the maximum scatter that can be expected. This sample is, however, sufficient to recognize that these 6 arbitrarily chosen tubes all manufactured by Ultron vary about as much as the TAD 6L6-WGC differs from the Tungsol 5881 (i.e. two different suppliers!) in the right hand section of the figure.

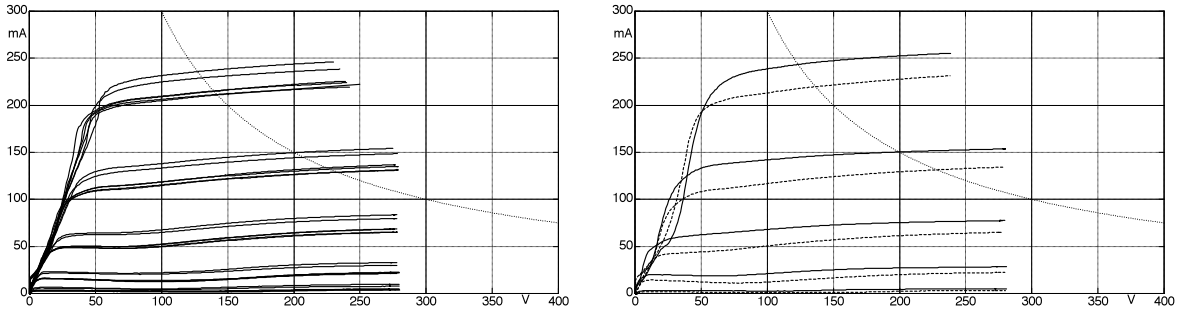

Fig. 10.5.41: Output characteristics: 6x Ultron 6L6-GC (left), Tungsol 5881 and TAD 6L6-WGC (right).

Unfortunately, the "matching" of tubes does not get rid of the problem. A comparison test as mentioned above elucidates: "*moreover, the tube pairs need to be optimally matched. In other words, the idle-current needs to be the same in both tubes as exactly as possible. The pair supplied by Tube Amp Doctor was perfectly in tune. We measured a deviation of only 2 mA. A mismatch of more than 5 mA would cause crossover distortion, and weak and inharmonic sound.*" Figs. 10.5.38 & 39 have already shown that equality in idle-current (bias-current) does in no way guarantee equality in the characteristics. Also, the term "transconductance" does not even show up once in the test report, just as power measurements, frequency responses or characteristic curves are completely foregone. Rather, the insights won are limited to blanket judgments such as "*the KT-66's are, in principle, HiFi-tubes and were deployed in 200-W-Marshall tops.*" Now, that indeed is a surprise. Not so much because 'in principle' all tubes should be HiFi-tubes, but more so because 4 KT-66 can hardly generate 200 W. Michael Doyle writes in his Book on Marshall that KT-88's were used in the 200-W-power-stages – that makes much more sense. And another citation for all students of psychology who need a quick additional example for their exam: "*Steve Ray Vaughan had a quartet of KT-66 in his famous Dumble Steel String Singer amp. Anyone who knows Stevie's album 'The sky is crying' already knows fundamentally how these tubes sound.*" In principle like HiFi, of course, don't they? Once you are aware of that, tube tests become rather dispensable – at least in principle.

There are some indications of this insight filtering through a bit; in a more recent test (Gitarre&Bass 3/2009), we read: "*Another problem in my testing was the possibility of a complete reversal of the results, depending on the amplifier*", and "*occasionally, only little remains of the clear differences that are experienced directly in front of the amp.*" What does remain is least one question: is it possible that a Chinese KT-66 can be "*through and through authentically*" sounding like the old MOV-originals, although its data (at U_a = 50 V) differ by a factor of three (!) from those in the old MOV datasheet? No, this is not proof that datasheets have no connection to the sound: every sound is based on voltages and currents, the correspondence of which is depicted in characteristic curves. And if that weren't necessarily so, we wouldn't have to so carefully match the plate-current, either, now would we?

