Vintage Wideband Audio Transformers

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Large, high quality wideband audio transformers are still in demand even though the forward motion of electronic engineering has all but eliminated the need for them in most modern circuitry. The dynamics for this apparent refusal of defeat requires more than just a few lines of explanation so that will be left for another paper. Suffice to say that in the high end audio world, both on the recording end and the consumer playback end, high quality input and output transformers, new and used, are only getting more expensive and harder to find. Is there a difference between large old school input/output transformers and the modern varieties available on demand today? Yes, with the exception of a few boutique companies most modern transformers have very good advertised specifications but show their price point manufacturing when directly compared to some iconic early examples from the 40's to the 60's (the manufacture of a relatively small number of good old school transformers did continue into the 70's & 80's). That isn't to say that manufacturers like Jensen, Lundahl, Sowter and others don't currently make some excellent transformers that can sound great in the right circuits, they all most definitely do. While sound is a very subjective perception not many "golden ears" engineers will choose a JT-115K-E or competitors equivalent over a K-241-D. Granted the K-241-D sells for $500.00- $1K and the JT-115K-E is more in the $100 range so why does demand only drive up the price of the K-241-D? Because the Altec Peerless model is one of the best sounding input transformers ever made. You must be saying to yourself why the hell doesn't one of the big guys introduce models based on the same engineering as the Altec Peerless types? I spent a lot of time and money looking for an answer to that question. In this paper I'll write about some of the things that I've found.

On some web forums the name Ercill Harrison comes up as the father of wideband transformers. We will revisit that claim shortly but Harrison was the chief engineer at Peerless at the time of the Altec acquisition. There is so little information on the internet regarding Harrison's history that most everything written is mostly speculation and hearsay. The reason for this informational void is pretty simple. Harrison was incredibly secretive about his work. The late and great David Sarser (Studio 3) had a relationship with Harrison which grew around the time of the Musicians Amplifier that Sarser had developed from the Williamson model. In a conversation that I personally had with Mr. Sarser several years ago Sarser said that Harrison told him directly that his intentions were to take all of his wideband audio transformer knowledge to his grave!! What did that do for Harrison's reputation? Nothing, nada, zip, in fact he was so secretive that today, no one, with the exception of a relatively few enthusiasts, even know who he was or that the sound they love on thousands of hit records and playback systems was pushed through Harrison's transformers. As of the date of this writing there isn't even a wikipedia page for him!! Moral of that story? Share your knowledge.

Anyone who has reverse engineered many early transformers knows that most of the techniques that Harrison championed were already in practice before the 50's and were mainly pioneered by the Western Electric/Bell Lab engineers. Bifilar and pied winding can be found in Western Electric transformers dating back to the 20's - 40's. There were so many excellent electromagnetic engineers at WE and Bell Labs it's impossible to hold up any one as the *father of wideband transformers*. The progression of transformer quality was a slow, mostly even progression that started at the turn of the 20th century. Electromechanical engineering advances as applied to wideband transformer manufacture didn't slow until mass market demand dropped as electronics got smaller utilizing fewer transformers and reduced power requirements. Now most advances are focused on miniaturization, price point, and efficiency rather than making the absolute best sounding transformers. That brings us back to the original question why is no one making audio transformers that are as well made as some early models. Demand is a relative thing. Even though there is a demand for certain vintage units there isn't anywhere near enough demand to set up a manufacturing line to build many units of one particular model, especially when one considers all of the manufacturing obstacles that need to be addressed.

Lets look at many of the details that make vintage wideband transformers special from other transformers. I'll use the Altec Peerless K-241-D/4665 input/output transformers for an example (yes, on the Altec spec sheets the K-241-D was listed as an output transformer as well as input). The K-241-D and the 4665 are basically the same transformer in a slightly different package. Unfortunately, the 4665 does not have the center tap leadouts on the secondary which is the only difference between the two models. The first thing to understand about these transformers is that they were engineered by men but they were manufactured mostly by women, especially the physical winding of the coils. This may seem like a slightly sexist statement but the reality is that women, *in general*, have a *much* better temperament when it comes to the patience needed to perform the difficult winding techniques used on these types of transformers. The winding machines at the time were not the programmable types used today. Most early machines had to be set up by a technician then ran by very highly skilled female winders. The skill level of those winding wonders can not be over stated. I can say from experience that winding 34 layers of pie wound #44 wire takes patience that very few males can ever conjure. While I couldn't build anything without using the term "*f*@k me"* every five minutes or so, I'm not the kind of guy who throws stuff around the shop when the going gets tuff. I have what I refer to as selective patience, a personality quality that keeps me focused on making something work when the cosmos seems to be working against it. Winding pied layers of #44 wire takes me to the limits of not only my patience but my clumsy male dexterity as well. On top of that, since the female wonder winders went the way of the doo doo with the golden age of audio transformer manufacture, there are no mentors left to pass the trade along. Most of the women weren't associated with the market end of their work so you will not find them participating in esoteric audio forums eager to set the myths straight.

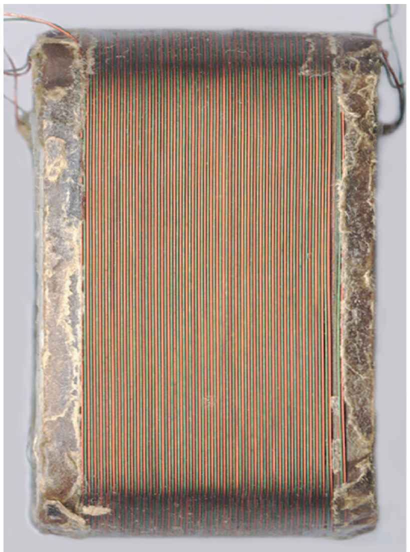

Fig. 1 A scan of the bifilar wound primary of a K-241-D coil. Note there are no crossovers. Each half of the primary consists of three layers wound one directly over the last.

Fig. 2 A scan of the pied secondary. This scan doesn't show the size very well but those margins are only 2mm wide. This is a very challenging wind to pull off one unit at a time.

The two most obvious differences between the Peerless K-241-D and most other input transformers are the bifilar primaries (Fig. 1) and pie wound secondaries (Fig. 2). Both techniques can be found in some earlier Western Electric models. The reason for both winding styles is for balance between halves of the same windings. The K-241-D/4665 have the same symmetrical balance between winding halves as a proper humbucking coil pair. By winding the primaries with two conductors side by side each winding half has the exact same physical association to the core. In electromagnetics proximity is everything. The farther a winding is from the core the less interaction it has with it. In other words the windings don't all couple with the core evenly. Also, there is more wire on the outer windings because the coil grows in size with every layer. More wire means more resistance. When the winding halves are bifilar wound together each winding bares the same relationship to the core at any given turn. The same is true for the pied windings only instead of winding two wires side by side, two complete windings are wound side by side thus also retaining a consistent relationship to the core at any given turn. These balancing techniques are different from most other similar transformers that use the standard 1/2 pri, 1/2 sec, 1/2 sec, 1/2 pri arrangement (sometimes augmented with more interleaving). In this standard arrangement the each winding has a a slightly different physical association to the core and therefore uneven electromagnetic coupling. This causes a small imbalance between winding halves with differing physical distances from the core. Western Electric usually developed circuits mathematically and they often maximized every part of the circuit. It was not unusual for the WE engineers to compensate for this coupling/resistance problem by adding a few turns on each winding with the number of extra turns increasing as the distance of the windings to the core increased. This would ultimately keep the inductance balanced between outer and inner winds but it would throw the dc resistance of the winding out of balance. To compensate for this the engineers often wound the outer windings with slightly heavier wire to reduce the extra dc resistance of more turns or larger coil diameter. The WE engineers were great at this, other companies not so much and I don't see this practice in many modern transformers that I dissect. The nice thing about the Altec-Peerless bifilar-pied technique is that balance isn't an issue and as long as the wire used for each half of the primary or secondary is consistent, inductance, dc resistance and winding capacitance will all be balanced. The not so nice thing is actually pulling it off.

When audio transformer demand was high most transformer coils were made on gear or cam machines that were setup to wind a dozen or so coils at a time. In practice layer wound coils wound with one or two wraps of glassine or Kraft paper between each layer is much easier to wind on a spindle with multiple coils being wound simultaneously than it is to wind them one at a time. Even when they were wound a dozen at a time the reject rate had to be enormous and highly unacceptable by today's standards. Winding pied winds of #44 wire led to many breaks and four out of the seven K-241-D's and 4665's that I have dissected or rewound had one or more breaks that had been repaired. Stopping a machine in mid layer to fix a break takes a lot of time, stunning patience, and a quick reaction time due to the fact that it's nearly impossible to use an early sensing switch because the #44 wire breaks before tripping even the most sensitive switch. Often photo sensors don't pick up wire as fine as #44 so the winding personnel had to watch carefully and react instantly to a wire break that obviously happened frequently. It is relatively easy to set up a winding machine for bifilar operation and I have never seen a break in the primaries of the K-241-D/4665. Although many of the dissected units had repaired breaks in the secondaries, the repairs were not the reason most had failed. The failure of these transformers in service has to do mostly with three factors. The first is that both models were recommended as output transformers for some of Altec's tube mics. They were occasionally fried in that application for various reasons. The second reason for failure is one that will be discussed in detail shortly but has to do with the potting of the coils. The third reason is simply the fact that they were not hermetically sealed and often the potting in the case was insufficient which, in the case of the 4665, allowed the plug terminals to corrode from the inside out (Fig 5 next page).

I want to discuss the second failure factor in detail because it also speaks to some of the aforementioned problems in manufacturing these transformers. The photo in figure 3 shows a freshly wound Altec-Peerless type 4745 coil. The 4745 transformer was the input transformer that was used in the Altec 250 SU 458 tube microphone preamp. It is almost identical to the K-241-D/4665 coils except that it has 46 layers of pied wound # 44 wire as opposed to the K-241-D 34 layers. That 4745 coil was a nightmare to wind a one-off unit. Under the freshly wound example there is a scan of the original coil as removed from the cases with case potting removed (Fig. 4). Notice the size difference? I'm not a sloppy winder and the new coil is wound as tight as one can possible wind # 44 wire without breaking it every few turns. *The reality is that the laminations can't be placed in these coils until the coils have been vacuum potted and ALL of the air between all of those layers is removed.* That reduces the winding outer diameter enough so they fit into the core window. It wasn't until I found this out in practice that I finally figured out why most of the units

Fig. 3 A scan of a newly wound 4745 coil. These have more turns on both the primary and secondary than the K-241-D.

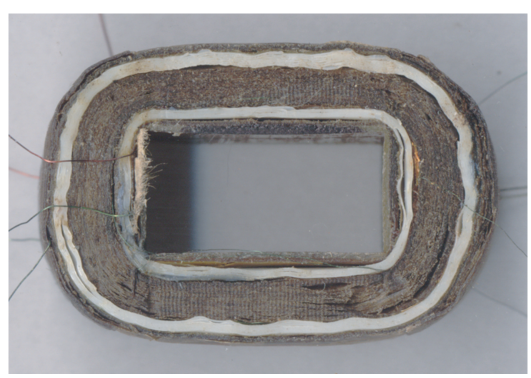

Fig. 4 A scan of the original 4745 coil. Note compression after vacuum potting.

that I have dissected have wavy wire rows (see figure 6). For a couple years all I could do was speculate how this could have happened during the winding process. It turns out it didn't happen during winding. It happens during the critical vacuum potting. Another hugely undesirable byproduct of the vacuum potting operation is the fact that the turns at the edges of the borders have a tendency to loosen with the reduction of the coil diameter as the coil shrinks when the air is removed. The borders on these are very narrow and, since they were cut from multiple spindles, the borders are usually uneven with one being very close to the coil edge. The loose outer wires tended to fall out of the coil !! (see figure 7). These wires swinging in the breeze tended to break if the transformer took some physical abuse. Of all the obstacles that had to be overcome to wind these coils accurately and faithfully, one at a time, it was the initial potting process that turned out to be the greatest hurtle.

Fig. 5 A scan of the inside of a 4665 case. Since these are not hermetically sealed many of the units that fail look like this inside.

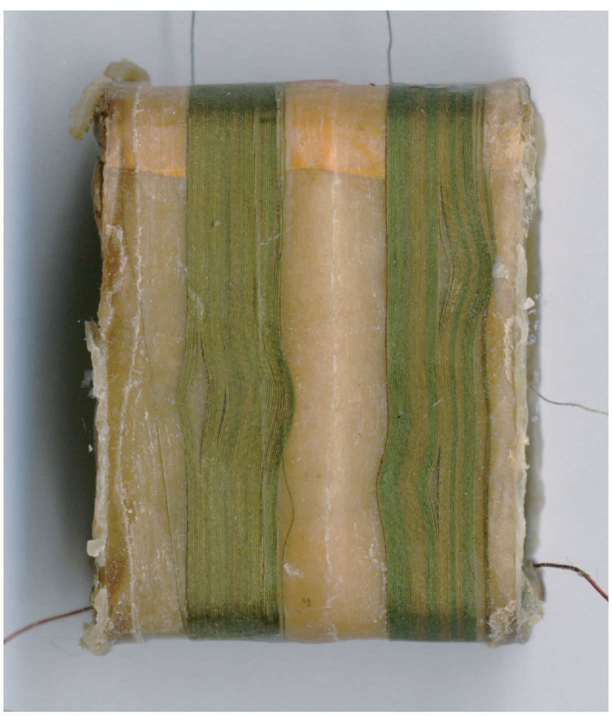

Fig. 6 A scan of the wavy winding rows that distort when the coil is vacuum potted. This tends to defeat the wire over wire winding benefits.

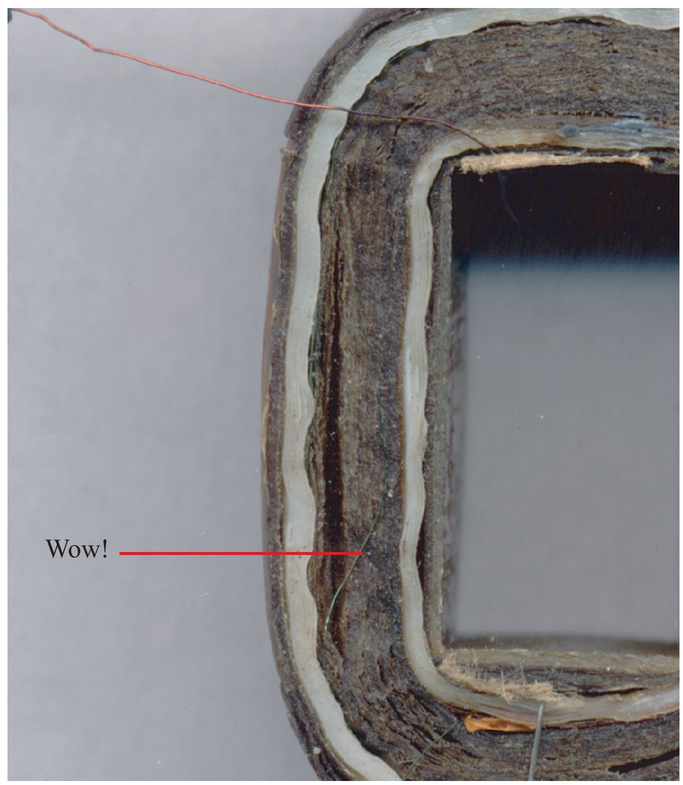

Fig. 7 Here is a scan of some of the #44 wire falling out of the 4745 coil. This wire was not dislodged during the dissection. It is a factory original feature and this coil passed quality control anyway. Notice the ripples that are visible in the white Teflon insulation. That happens as the coil's diameter shrinks as the air is drawn out. The result on the windings is the wavy rows shown in figure 6.

The topography of the Altec-Peerless techniques actually has more to do with balance (which actually amounts to distortion) and that reduces leakage inductance giving greater bandwidth. As far as the low end is concerned it is controlled by the primary inductance. It will fall off 3 db at the frequency where the inductive reactance of the primary equals the primary impedance. It will fall of 1 db at 2x the primary impedance and .5db at approximately 4x the primary impedance (Wolpert). The trick here is to keep the primary impedance low by using as few turns as possible to obtain the needed primary inductance (246 turns for the K-241-D/4665). The high end of a transformer will be down 3 db at the point where the normalized impedance equals the reactance of the leakage inductance. Simplified, the leakage inductance can be thought of as the capacities of the windings and the balance can be thought of as the evenness of the capacities from the input leads to the output leads (see figure 8). With a standard wound coil (one winding at a time concentrically) the bandwidth is usually extended by interleaving parts of the secondary and the primary alternately. This keeps the voltage potential between adjacent windings low. That in turn reduces the interwinding capacitance. The increased number of interleaves improve the bandwidth to a point where too many interleaves begin to produce diminishing returns and becomes not worth the effort of additional interleaves. This concept put another way means that the first interleave has the most affect on the capacitive reduction. The only interleaving in the Altec-Peerless models is the secondary interleaved between halves of the primary. In order to further reduce capacitive interaction between windings in the K-241-D and 4665 Altec chose to use an electrostatic shield which is insulated from the secondary with multiple wraps of Teflon sheet. Teflon has superb dielectric qualities in this application. Shields between the primary and secondary in audio transformers get some bad press on various web forums but in this application the result speaks for itself. In fact the shields alone improve the longitudinal balance substantially and their use here is very similar to the *box* type shields that are used in instrumentation wideband transformers. Box shields in instrumentation transformers actually box in and completely enclose both windings. In the Peerless-Altec transformers the shields have only two wraps of .00075" Kraft paper separating them from the primary winding wires. In between the shields and the secondaries there are 5-7 wraps of .005 Teflon sheet which almost eliminates capacitive interaction from the grounded shield and the secondary. As a side note shields for pickups also get bad press in guitar forums. The use of several wraps of Teflon between the wire and the shield in this application preserves the sound while making the pickup quieter. The K-241-D/4665 are in the 20-20 series so the high end extends past 20K Hz. There is no need for more interleaving, more importantly, there is absolutely no room in the core window for any additional Teflon and shields which already make up a good portion of the original fill.

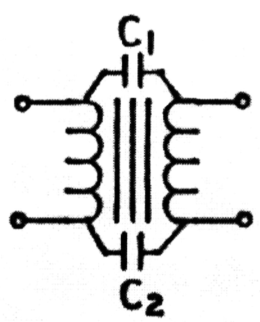

Fig. 8 A schematic drawing showing longitudinal balance. Ideally C1 should equal C2. (Wolpert/McLyman)

The term balance as it's been used so far includes not only longitudinal balance which is a transformer's primaries ability to prevent longitudinal signals that have been introduced in the power lines from being transferred to the secondary of the transformer (Wolpert), but also the capacitive balance between the secondary halves. The longitudinal balance is determined by the capacitive balance in the primary and some other factors like shields between windings. The longitudinal balance in the K-241-D specifications is listed as providing at least 50 db of attenuation of longitudinal currents. That is a very good figure.

Topography only gets you so much capacitive reduction and winding technique will make or break any gains made by topographic advantages. When manufacturing layer wound coils the idea is to wind one layer of wire over the last in such a way that the wires are stacked one directly over the last with as few crossovers as possible.

Fig. 9 This diagram shows wire over wire winding advantage.

From the diagram above it can clearly be seen that staggering the wires in adjacent layers increases the number of wires that any given turn will have capacitive interactions with in the layer above and below it. The capacitive effect is created by the voltage potential difference between the layers so turns that are right next to each other in the same layer have very little voltage potential difference therefore have very little capacitive interaction. Ideally this wire over wire idea should cut the coil's interwinding capacitance almost in half but it doesn't work quite that well in practice. Both the primary and the secondary of the K-241-D/4665 (and the 4745) are wound with this technique. One thing I noticed while building up a database for these transformers was that the measured capacity of the windings was often quite different from one another. The capacities differed even though the engineering details of the coils were proven to be consistent from example to example. From what I've seen so far these coils didn't change much through the entirety of their production. I believe that the interwinding capacities differ from example to example due to the potting/shrinking problem covered previously. Those wavy winding rows that occur as the coil is vacuum potted absolutely affect the final capacity of the windings. Luckily, the performance of the K-241-D is still great even with this engineering snafu.

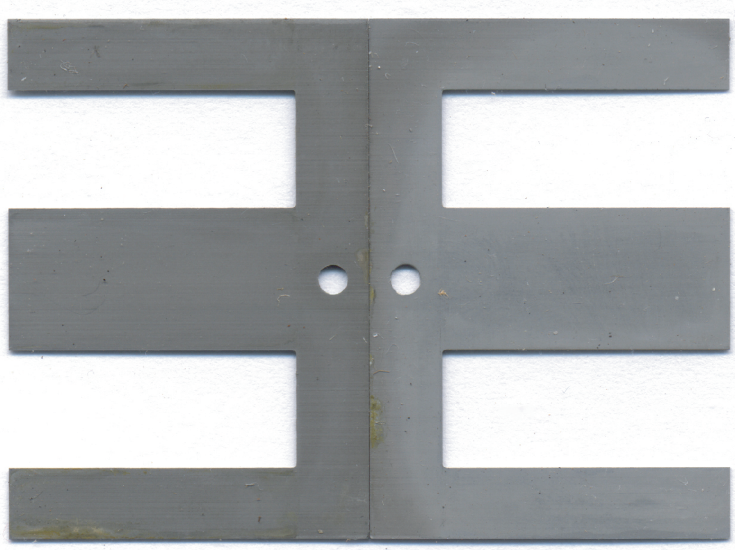

Fig. 10 A scan of the two different types of laminations used in the K-241-D/4665. The alloy of the laminations is the same but the processing during the annealing stage was altered. It appears like an oval object was placed on top of the lamination on the right during the anneal.

Core Laminations

Core alloys used in vintage transformer manufacture is the subject of massive speculation on the internet. It was by far most common for manufacturers to design their transformers using stock alloys chosen from a catalog. In fact it was very unusual for a transformer company to actually specify a certain alloy for a production run. Sometimes a design that had mostly superb sonic characteristics under measurement might show a deviation somewhere in the frequency spectrum. It could be a ringing or resonance that shows after the practical implementation of the design. Ercill Harrison had some tricks for reducing these flaws and this information is much harder to deduce from reverse engineering. One way that Harrison tamed unwanted ringing in a transformer was to slip several laminations of a different alloy into the stack. In an e-mail conversation that I had with David Sarser before his passing he wrote: "Ercil used a mixture of hypersil and c core to balance and reduce the ringing. I noticed that when he took me through the plant when they were making a 200 trial run of transformers for my amplifier for Hallicrafter. He didn't expect me to observe that and asked me not to reveal what I saw. The picture is still in my memory." Note: Mr. Sarser expected me to pass this info as he waited until 2005 to reveal it.

The laminations for the K-241-D/4556 were not custom alloys. I'm holding on to the exact alloy as it was an expensive detail to determine and required gas spectronomy*. I will say that it was stock out of a catalog. Engineering details of any product can morph over time and multiple production runs. All of the laminations for the K-241-D and 4665's that I have dissected are of the same alloy with no other alloys involved. I had dissected several of these transformers and on the fourth one I noticed something about the laminations that I hadn't noticed before. There were 10 or so laminations from the stack that looked like they were covered during all or part of the annealing process. The photo in Fig.10 on the previous page shows this subtle lamination processing difference. The lamination on the left is one of the laminations that make up most of the core stack. The lamination on the right is one of the 10-12 laminations that differ from the rest. Looking closely at the lamination on the right the coloring on the outer edges matches exactly the coloring of the entire lamination on the left. The lamination on the right looks as though an oval shaped object was placed over it before or during the annealing process. They were probably covered with metal as the annealing process can be in access of 1000F.

I went back to previous dissections where the laminations were retained and found that all of the K-241-D's and 4665's had the same dozen or so differing laminations. The color difference went unnoticed before because on the earlier dissections the discoloration was much more subtle. In the 50's and 60's ordering up custom alloys and stamping was expensive but requesting annealing specifications for existing alloy choices often didn't add to the cost at all. The processing difference of the minority laminations was intentional and the full details may have indeed been taken to Harrison's grave. Lamination annealing details are not the kind of thing one finds on company winding sheets.

In our modern world it is getting more difficult to experiment with alloy and annealing changes. While the technology has made all of the processes involved in both alloy composition and annealing cheaper and mostly automated, at the same time most all of the manufacturing has moved to Asia. It's been my experience that many of these companies are willing to be flexible with their processing and products but the back and forth, design changes, manufacturing changes, testing, language barrier, quantity minimums, repeat cycle takes much more time and money than working with a company a state or two away.

It is interesting to note that the laminations for the Altec Peerless 4745 input transformer, which is wound with the same geometry as the K-241-D/4665 only with more windings on both the primary and secondary, uses completely different laminations from the K-241-D/4665. The laminations are a yellowish color unlike any other laminations that I've seen out of any Peerless transformer that I've dissected to date. I could not have the odd colored laminations tested as that transformer was in for a rewind and it needed it's lams. There does not appear to be any processing differences for the laminations in the 4745. They are thinner than the K-241-D lams and there are many more of them.

The Altec/Peerless TB-103

The K-241-D didn't just appear out of the blue. In the photo in Fig. 11 the Altec TB-103 is shown. Note that this version does not have the Peerless addition to the name. The transformer is not dated but I suspect it was made just before the Peerless acquisition. The label is the standard label that Altec used during the "Hollywood" era. There are two versions of the TB-103. The version shown in Fig.11 is the round can TB-103 and the second version is the TBB-103 that was produced in a square can. The TB-103 round can had 25db of magnetic shielding and the TBB-103 square can had extra shields that provided better than 90db of magnetic shielding. The TB-103 and TBB-103 appear in a 1950's Altec transformer catalog that does not included the Peerless name anywhere in it. The catalog is available for free download at www.VintageWindings.com.

Fig. 11 The Altec TB-103 Input Transformer. This is the version with 25db of magnetic shielding. The case provides all of that shielding and there are no other shields inside. (there are electrostatic copper shields between windings).

The example in the photos was dissected and while the primaries are not bifilar wound, the secondaries are pie wound just like the K-241-D. This was apparently done before the official Peerless acquisition so I'm not sure how much input Ercill Harrison had regarding the pied secondary. Pied windings were quite common on some Western Electric models even as early as the 20's and 30's.

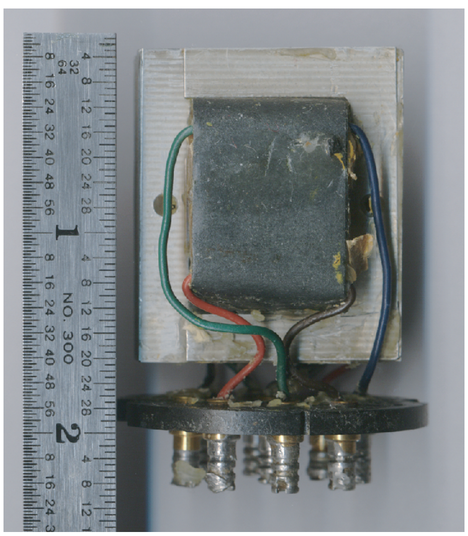

Fig. 12 The Altec TB-103 transformer out of the case.

I will say that there is some strange internal wiring going on with the TB-103 along with the strangest primary winding counts/layer that I have seen so far. The K-241-D was an engineering improvement in that the primaries were wound bifilar with slightly heavier wire than the TB-103 and with less windings which keeps the primary impedance low which, in turn, helps extend the low end response. The TB-103 is not listed in the catalog as an input/output transformer like the K-241-D and the 4665. It is an input transformer only.

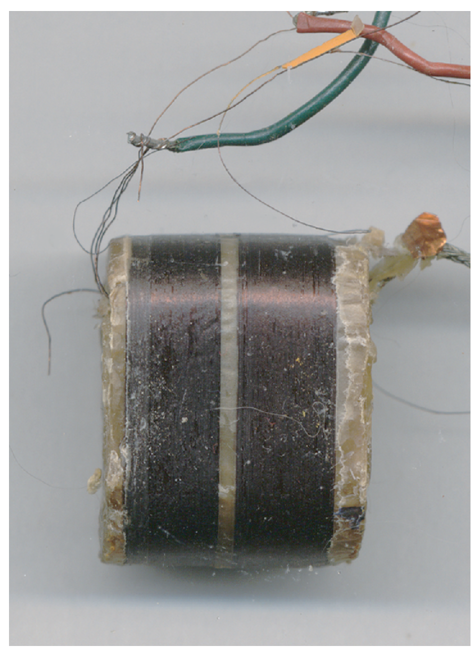

Fig. 13 The Altec TB-103 Transformer with the familiar pied windings.

The 4722

The 4722 is a bit of an enigma. Many old school engineers swear by them. Produced at the time when Peerless was a division of Altec they probably have the best sound one can obtain from the very frugal choice of materials that Peerless used to manufacture them. The only thing that the 4722 has in common with the K-241-D besides being a Peerless product is the bifilar wound primaries. The topography of the 4722 is about as simple as it gets. The bifilar wound primary was wound first and a non-split secondary was wound on top of the primary. The secondary is just one wind start to finish. That's it, no interleaving, no shield between windings. The coil and core are much smaller than the size of the can suggests due to the fact that there are extra shields under the exterior case. See figure 14.

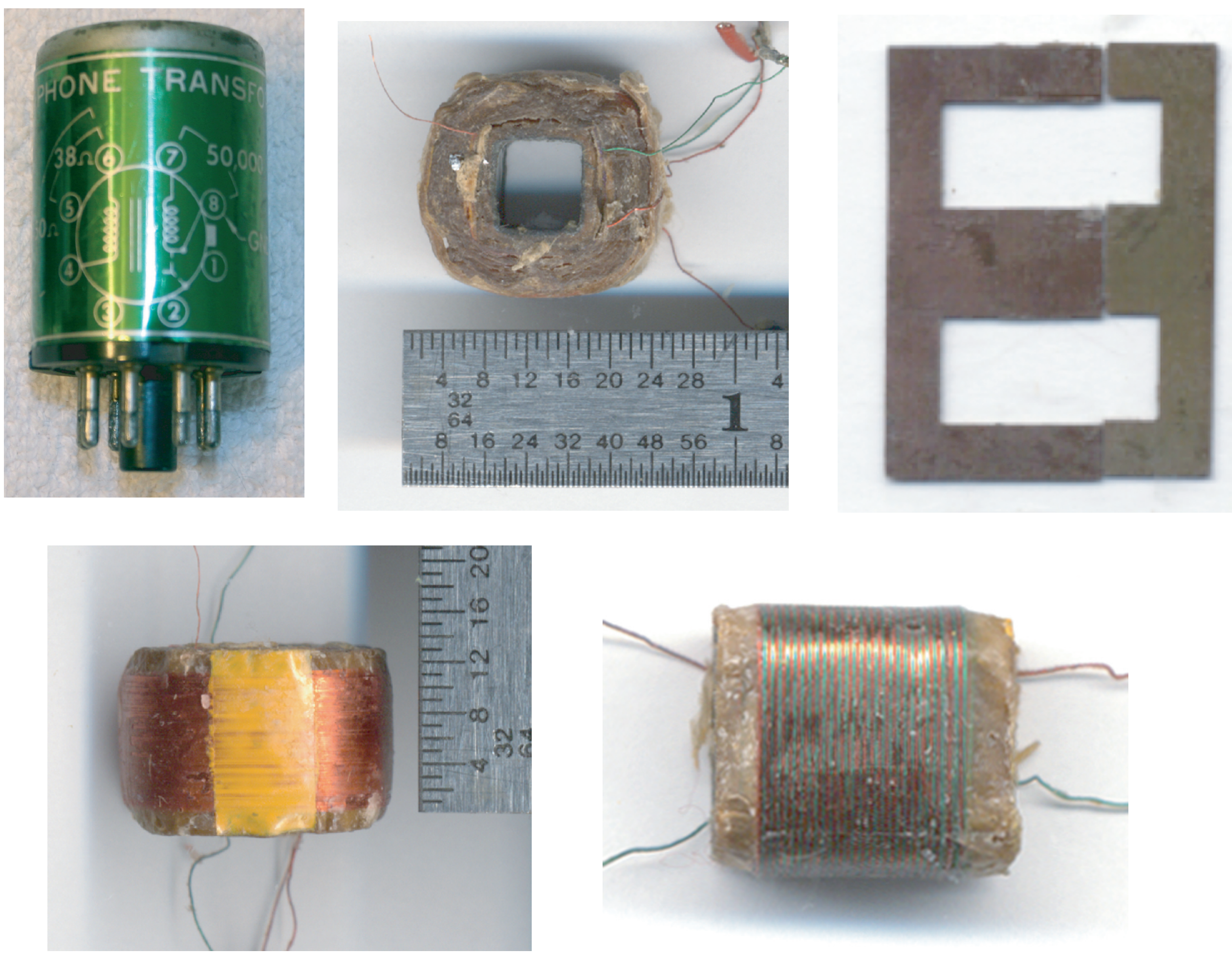

Fig. 14 A set of photos of the 4722. Note the different colors of the lamination E's and bifilar primary.

The photo at the upper right is of the laminations. The size of the transformer core suggests that it might be 80% nickel but the color sure doesn't look like any 80% laminations that I've seen. Unfortunately I haven't have the opportunity to have the lams tested for alloy content however there are two distinct colors as can be seen in the photo. I'm not sure if this is an alloy difference or a processing difference but both colored laminations are used in the stack. The core is grounded in the 4722.

Vintage Wideband Audio Transformers

In the 70's and 80's in-line recoding and broadcasting consoles became the standard. These consoles had limited real estate for large, arguably inefficient input and output transformers. At the same time solid state transistors and IC's made their way into production lines. That led to the miniaturization of components and circuits which reduced power requirements. In order to keep their products viable, transformer manufacturers began to utilize core alloys with a much higher nickel content. The high Ni alloys allow for low signal transformers to be made smaller and much more efficient. The thing about high Ni alloys is that they handle low level signals very well but tend to saturate when hit with a strong transient. There is much debate on the web regarding the pros and cons of 80% Ni magnetic alloys. The esoteric hi-fi forums tend to not like them very much. Most modern input transformers could not be produced without hi-Ni alloys.

The Peerless techniques were not completely lost in the 70's and early 80's. My Sony 3036 recording console is loaded with Jensen JE-115K transformers (before the JT version). The transformers in that board look just like current 115K's however they were made during the Reichenbach era with Jensen. After replacing several Sony channels with John Hardy mic preamps** I dissected one of the original JE-115-K's that were originally installed. After unwinding the standard non-bifilar primary I arrived at the very surprising pie wound secondary! Since then I have unwound several 115K's from the later Jensen era and the pied secondary is no where to be found.

There are still transformer coils being wound on spindles in a multiple coil fashion. Lundhl winds many of their modern transformers that way. I have not dissected one that uses bifilar or pied windings however. The problem with winding vintage type layer wound coils is that the materials that were used are not contusive to the automated techniques that are in use today. Machines are good with cellulose acetate and poly insulation materials but don't handle .00075 Kraft paper well because of it's tendency to tear. Most manufacturers aren't so keen on winding with #44 AWG magnet wire either. While it would be possible to wind modern versions of these vintage transformers with modern machines and materials the results would not be the same. The Kraft papers and glassine used in the early years were porous and the potting waxes would impregnate the fibers and significantly improve the dielectric insulative qualities of those materials.

Challenges in recreating the K-241-D

As previously mentioned the demand for input transformers isn't what it used to be. Setting up a production line to manufacture vintage type transformers simply isn't economically viable. Finding winding personnel with the necessary skill set is also a huge problem. So for now the only option is finding a way to wind them one-off. There are major economical hurtles to overcome winding them one at a time too. They obviously wound them on multiple spindles originally because it was more efficient to do it that way. It takes much longer to wind them one at a time. The cost of all of the needed materials has risen greatly over the last two decades.

When customers inquire about having a few K-241-D type transformers made they are shocked to find out that building them today costs as much or more as their vintage counterparts. People generally think that the cost should be in-line with the cost of a modern unit. The winding techniques alone take far more time than a standard bobbin wound or layer wound coil. There are more steps to the potting of the coils. There are different protocols for the annealing of the laminations. The materials come from five or six sources because modern coil winding suppliers no longer carry obsolete materials. There are three shielding cases instead of the modern standard of one. The shielding case sets alone come to around $50.00 each when purchased in small quantities. The reject rate for the coils is high due to the difficulty of the winding techniques employed and the delicate nature of the materials. Let's not forget the cost of the fairly elaborate vacuum oven and potting equipment. Goes on and on....

Winding the K-241-D one-off

It is very tricky to wind the K-241-D type coils one-off. That and the cost of production verse the retail value are the largest factors which keep these out of the marketplace. Machines that wind single transformers are really made to wind bobbin type transformers. They will wind layers nicely in a bobbin but winding without a bobbin is next to impossible without special tooling and wire guides that must be custom machined. Another problem is that when coils are multi wound on a spindle the spaces between the coils tend not to compress as layers are being built up (see Fig. 15). That is because the adjacent coil layers prevent that from happening. When the coils are wound one-off there is no adjacent windings to keep the margins from collapsing. The tension on even the thinnest magnet wire will tend to make the margins collapse and the wire will follow the depression and fall out of the edge of the winding. Preventing that from happening is one of the many tricks to winding these one off.

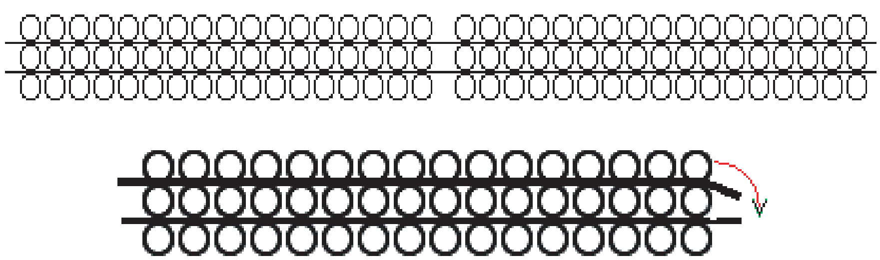

Fig. 15 The diagram at the top shows how the fragile .00075" Kraft paper keeps from compressing when several coils are wound on the same spindle. The diagram at the bottom shows the challenge of preventing the outer turns from sliding off the side of the coil when there is no winding on either side to prevent that from happening.

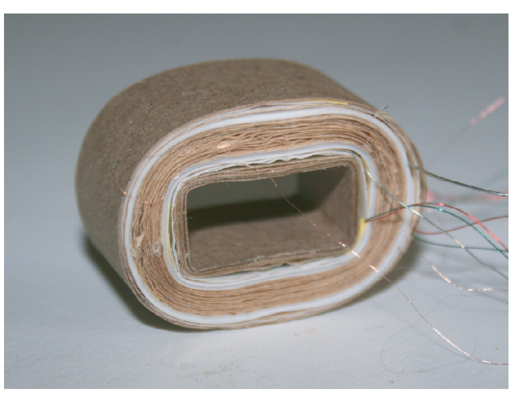

Fig. 16 A freshly wound K-241-D type coil wound by yours truly. Note the clean edges that look just like they were cut from a multiple spindle just like the originals. Exactly how I do that I'm not quite ready to reveal. That will be a good excuse for another paper. This coil is _exactly_ like the originals in every detail including all materials used to wind it. The Vintage Windings version of the K-241-D will be designated the K-241-P and will be available for purchase in the Fall of 2015 at VintageWindings.com.

Notes

* Gas Spectronomy has been the standard approach to determining the alloy content of unknown lamination samples. The equipment cost is well out of the reach of small to mid size winding manufacturers. Even the cost of sending a sample to a spectronomy lab is very expensive. Recently advances in electronics have made assessing alloy formulations much more economically feasible by use of an XRF Analyzer. XRF analyzers come in various sizes but the most common are hand held models. They are not cheap costing between $7K and $25K but are much less expensive to rent than leasing a gas spectronomy setup. Most large cities have companies that will rent XRF units. The last time I rented one the cost was $400.00/day, $950.00/week, $3000.00/month, $250/hr for training (1-2 hours required) and a $3950.00 security deposit. I had all my samples ready to go so my use of it was over in a day. The only time that I had gas spectronomy done it was $750.00 for one sample. The kicker here is that almost all laminations from the golden era of transformer manufacture were actually stock alloy formulations ordered out of a catalog, however, having conformation eases any doubts. Niton is a popular name for XRF analyzers and can be found at www.niton.com. They can be rented from Eastern Applied Research Inc., those folks can be found at www.easternapplied.com. Note, Eastern Applied is local to me, most cities have a job shop that will rent an XRF unit or perform analysis for you for a fee. Keep in mind that the analyzer will accurately give alloy contents, it will not tell you anything about how the metal was annealed. According to the fine engineers at Western Electric annealing has more affect on the final core characteristics than does the alloy in many cases. There are WE papers on annealing and more posted in the tech swag section at www.vintagewindings.com.

** The Hardy preamps come with a current JT-16 input transformer. It is wound with a proprietary winding technique that is briefly described in a Jensen white paper. The technique involves carefully winding the secondary by essentially winding shorter layers that are built up by winding in a back and forth motion but not traveling all the way across the full width of the coil. In other words the secondary windings are built up at an angle making the layers shorter that the width of the coil. The JT-16 is also only a 1:2 coil unlike the 1:10 or better ratio of the early high ratio step-up transformers. There are far less interwinding capacities created in a 1:2 coil than a 1:10 coil which has many, many more secondary windings. The JT-16 is an example of the previously mentioned modern transformer, by a modern manufacturer, working very well in a modern circuit.

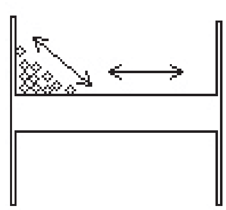

Fig. 17 This over-simplified diagram shows the idea behind Jensen's proprietary secondary winding used in the JT-16 input transformers. The windings are built up at an angle starting from a bottom corner. This drawing is not anatomically correct....