Tube Tester Usefulness and Accuracy!

This is yet another question I am often asked. So I will provide a little insite into these two topics. I am not a writer so give me a break on my communications style and long windedness!

I will start with usefulness:
The best tube tester is the electronic equipment in which the tube is used in. That is to say if you inserted the appropriate meters and other test equipment into the circuit (of the amplifier, or product the tube is used in) around the tube you want to evaluate, this would be the best tube tester and provide the most accurate and useful information on the tubes condition and performance in the product it is used in. This is just a fact! It is also not practical for anyone, except an engineer, or technician and even then it is costly to do!

The next best option would be similar to the vary early days of radio where the tube/set testers were used. In these testers you would, 1) remove the suspect tube from the radio, 2) insert a plug from the tester into the radio tube socket where you just removed the tube to be tested from, 3) you would then plug the tube you removed from the radio into the tester, 4) now you would turn on the radio and the tester, and you would read the condition of the tube on the meters. This worked for the old 4 pin simple rectifier/diodes and the triode amplifier tubes in early radio, but it wont work, or provide enough information in the more modern electronic equipment, radio and TV's of the later generations. Why? Because the circuit configuration and varying operating voltages/currents and signal waveforms would require a lot of specialized test equipment. The cost for the many adaptors and wide range of equipment required would be way to high. Yes, it could be done, if you had the money, but it would not be cost effective for any business and would expose the hobbyist, or customer at home to some serious danger including potential death from an electrical shock.

Enter the Service Tester:
The service tester was developed for the telephone/radio/TV/communication and the industrial electronics industry to provide basic tube testing capabilities to help technicians and engineers to locate weak, bad, or defective tubes. The early testers were emission testers only. These worked just fine in the early days of the industry before the circuits, and tubes became so sophisticated!

Over the years there were many approaches in tube tester designs, and thus the features, accuracy, and the tests available differ by make and model. Not every manufacturer had the same goal. Early on some just wanted to focus on simple low cost units to find weak, or just bad tubes. Latter as the industry grew with many companies jumping into the tube tester market as the number of tubes grew and the consumer electronics industry grew too.

In all case of the service testers they were at best a set of balances and trade offs in the evaluation of the tubes vs., the cost of the equipment. Even the best of the service testers made trade off's in design to allow for simple use, features, and accuracy level, balanced by the price for the tester.
The service tester was a piece of test equipment to be used by professional engineers and electronic technicians to help in the process of repairing tube equipped electronics. So the equipment was designed with the understanding that those using it were both knowledgeable of tube operation (technology), the equipment the tube to be tested was used in, and how the tube tester worked in evaluating the tube. This is more often not the case today!

These testers (any make, or model), are just as useful today in servicing vintage equipment as they were back when they were originally used, and as designed for, to find weak, or bad tubes. There are many types of service testers. The usefulness of each make and model will vary with the type of equipment you are servicing. Of course the age and actual usage, or wear on it will have a big impact on its condition and usefulness in testing tubes today. The condition of key parts like the power transformer, meters, precision components, tubes used in the tester, and capacitors will greatly impact the test results obtained and accuracy level you can expect to get!

The next and last tester is the Laboratory, or quasi-laboratory tester:
The quasi-laboratory models were testers that came close to laboratory models, but did not provide true laboratory level testing where all tube parameters could be independently setup for each tube element at either typical circuit operating potentials used, or at the tube data sheet values. This unique group of testers were between the typical high end service tester and the low end of the laboratory testers. Some designs were better than others! Overall some were vary good testers.

The true laboratory tester was the closest thing to a tester that could perform a wide range of tests to a high level of test accuracy. However, these testers did not perform all possible tube testing either. Example, no laboratory tester could test for the actual capacitance between tube elements. This level of tube testing had to be done using other laboratory test equipment and was only done in a laboratory environment and never in the service environment. High end laboratory units would allow for the setting of voltages and currents on each tube element and measure the characteristics of the tube at different operating ranges. They could be used to evaluate the tubes actual performance, and measure the tubes specified values when compared directly to the tubes data specification sheet. They could be used to do quality control evaluations in factories where tubes were being produced. In addition tube design engineers could evaluate a new prototype tube design on these testers before approving the tube for production. These are by far the most useful of the tube testers. But they are also vary big, heavy, complicated, and present the greatest potential for operator injury (shock hazzard) and for damaging a tube being tested, if enough care and attention to detail is not used in setting it up. Here again between different makes and models you will find a range of capabilities and features as well.

The problem with usefulness today is that testers are not always being used as they were designed to be used, and people have much different expectations and often a lack of knowledge of the testers actual capabilities vs., what they either expect, or actually need them to do. Plus these testers are all quite old now and their actual operating conditions vary widely!

So effective usefulness of a tube tester will depend on your needs as to what kind of tubes you are testing, what specifications are important to you, what is the equipment the tube is being used in, and how much accuracy in the test result is required. Then you can decide which tester make and model you choose to use. There is a cost per Gm value at the price some tubes sell for today! So the choice made can affect the costs and actual value you get from the purchase of a tube.

Usefulness Example:
A service tester that only has a short test using a neon lamp will generally (not all models) only test for shorts in the range of below 300,000 ohms or so. Some other models using lamps to test for shorts and leakage will test to 25 Meg Ohms! So if you are using a low end, or mid range service tester with a neon short lamp to test tubes used in high frequency communications equipment looking for shorts and leakage above 300,000 ohms you would not find a bad tube with inter element leakage well above 300,000 ohms. You would have to either just instal a new tube, or trouble shoot with much more high cost test equipment to locate the problem that a good service tester could have found quickly. In the modern circuit applications of some audio equipment you may have need to test for leakage of as high as 2 meg ohms. The 300,000 ohm test would not catch a bad tube here either. Of course this is, but one example of many!

Another typical example: Many testers were not able to accurately measure Gm values at or above 15,000 micro mho’s. This even when the scale on the meter went to 30,000 micro mho’s. This was a result of a simple design error in some models, or failure to correct for known high mu tubes/tester characteristics. So here again the actual usefulness of any tester will depend on its features, their characteristics (specifications) and how the equipment will be used, and what level of testing is needed. If you buy and sell tubes you will need the highest level of capabilities. If someone in vintage equipment repair needs a high frequency tube (of that date) and you can not test it for high leakage in the meg ohm’s, you may be selling a bad tube that might work well at low frequencies, but not at the high frequency as it was designed for, or for use in the equipment it was designed to work in!

Summary:
The best tester is the equipment the tube is used in. The next best option was just to substitute a new tube back when tubes were plentiful and cheap too. As for the tube tester the laboratory tester would be the best option, the next best is a high end service tester. For easy of use and reasonable accuracy for the overall tube environment the service testers are the most cost effective. The high end units provide the best usefulness with the best test features and specifications. Last, but not least are the low cost mutual conductance (figure of merit) style testers useful for just locating weak, or bad tubes and when you don't need to know the actual Gm value, or need to worry about finding tubes with high inner element leakage issues. However, even in this situation there were some low cost units that did a good job at leakage testing even if they did not provide actual direct Gm test values.

Mutual Conductance Testers:
Dynamic Mutual Conductance testers:
Direct Gm measurement - Best and easiest to get actual Gm values with.
Percent quality convertible to actual Gm - Good if you have the charts, or want to do the math.
Simple numeric scale convertible to actual Gm - Good if you have the charts, or want to do the math.
Arbitrary figure of merit 0-120 convertible to actual Gm via a special chart in the operators manual (not vary accurate) and not as useful.

Mutual Conductance measurement circuit design:
Arbitrary figure of merit 0-100 or 0-120 **Not convertible to actual Gm** and not as useful. This method will give good/ ? /bad test results only, and can only be used to do rough comparisons between two tubes. It can not provide direct Gm test values.

Now I will cover accuracy:
This subject will by necessity require some math and some technical discussion as well!

Basically the accuracy of any equipment is depended on the tolerances of its sub systems and components! The tube tester is made up of several sub system, or individual measuring circuits which other wise could be independent of each other. But the switches in the tester are used to configure, or connect the various sub circuits to measure the appropriate values under test to the level of accuracy designed for. You may notice that many components of +/-10 to 20% in say a laboratory tube tester and it may have an overall accuracy of Gm (mutual conductance) measurement of +/- 1.5%. This is because the measurement circuit will have much tighter tolerance in key components of +/- 1.0% or better, while the supporting circuits need not have this same tolerance value requirements.

The most important accuracy measurement in a tube tester is the mutual conductance value of an amplifier tube, followed by the short/leakage tests. Gm is the one specified value of an amplifier tube that tells a lot about its condition, and in a tubes specification data sheet that tells the most about the capabilities of the tube as an amplifier tube.

The average accuracy of the better service testers is +/- 10% and for the lesser capable testers is from +/-15% to 20% while the quasi-laboratory models will typically be between +/- 10% to +/- 4% and the full laboratory models will be between +/- 4% to +/- 1.5% . When you think of this percentage you need to understand what this means.

The actual true, or absolute Gm value of any tube is never really known, because all measuring instruments have a specific measuring tolerance value, and nothing can be actually measured to its absolute value. So we start with a Laboratory tester of +/-1.5% which means the tube measured could have a Gm value within a range of -1.5% to the high of +1.5% from nominal, or a range from low to high of 3.0%

So lets work with a tube with a **nominal** specification of 6000 Gm. A calibrated laboratory tester with a tolerance of +/-1.5% confirms it measures 6000 Gm.

This means the tubes actual Gm could be as low as 5,910 Gm and as high as 6,090 Gm for a range of 180 Gm. Now we measure this tube with a service tester which has a calibration tolerance of +/-10%. This should produce a test result between a low of 5,319 Gm and a high of about 6,699 Gm for a range of 1,380 Gm. What! Why not a low of 5,400 Gm which is -10% from the 6000 nominal Gm of the tube! We have to go back to the confirmed tested Gm of the tube with the Laboratory tester. The worse case low Gm from the lab tester at -1.5% which was 5,910 Gm. As the Bogey tubes measured value with the laboratory tester allows for a 3% Gm range and as the calibration of the service tester is set by the specified Gm value of the Bogey tube you must consider the 3% range of the tubes stated Gm value to understand the actual accuracy range you are dealing with. So when measured on a +/-10% calibrated tester the worse case would be 5,910 Gm less -10% which is equal to 5,319 Gm. Then 6,090 Gm high side plus (+) 10% would be 6,699 Gm, or a range of 1,380 Gm. In the real world this would mean that a tube that had a reject point of 3300 Gm with the above test data would still have a Gm life of 37.96% or at least 2,019 Gm left available worse case, before hitting the reject point of 3300 Gm. Having said all this, from a real world perspective you can ignore the +/- 1.5 % value of the laboratory tester as negligible compared to the bogey tubes own tolerances values.

To under stand accuracy you must think of both individual circuits and related circuits that make up a system. A tube tester is a miniature system in that it uses different circuits configured accordingly to provide various measurements. Thus there are inner relationships of parts, circuits, and the over all system values as well. The accuracy of any tube testers specific measurement is controlled by the design standards established based on the degree of required accuracy desired/needed, parts used, and environmental conditions it is used in!

Now having an understanding of the accuracy measurement itself, you now need to understand the accuracy of the tester when trying to compare the measured tube value to the tubes data sheet value and the tubes actual value when compared to this data sheet test standard! WOW!

I will again use a 6L6 as the example!
A 6L6 data sheet calls for a new tube to have a nominal value of 6000 Gm!
This is based on the following tube specifications:
Plate voltage of 250,
Screen Voltage of 250,
A DC bias voltage of - 14.0 volts,

Tube testers are either of the proportional operating value type, or they are of the actual operating value type. Laboratory testers are of the actual operating value type. Most all service testers are of the proportional value type. That is they apply voltages/currents at a proportional value to the full actual voltage/current values, but at chosen values that will be vary close if not exactly the same Gm values as listed in the tube data sheet, assuming the tube itself was within its nominal tolerances also.

A tube has many Gm values depending on the actual voltages applied to each of its elements.
There are several points along various operating values at which a tube will have the same Gm (mutual conductance) value. This creates an additional issue of measurement accuracy. That is the difference between the <u>service tube testers</u> measured value, and the actual value of the tube as compared to the data sheet test (from a laboratory tester) when compared to the service testers test result.

So a 6L6 ideal nominal bogey tube = 6000 Gm and say it measures 6000 Gm. A service tester should be able to measure this tube at 6000 Gm within +/- 10% to +/- 15% (depending on tester) to meet the typical accuracy test results of a typical service tester. Under this situation you are now comparing apples to apples. The difficult part here is that tubes themselves cause variations in the test results due to some of their own operating characteristics. So if one 6L6 has a different forward grid current, this will effect the DC bias voltage load on the tester and thus the actual DC bias voltage applied to the grid of the tube.

The DC bias voltage works with the signal level to establish the measured Gm value. Services Testers can not set each operating voltage to each tube element separably. So you end up with a compromise of design and accuracy. Back in the day, this was not a major issue as service testers were used to find weak, or bad tubes which they did well. But today they are being used to evaluate, QC (Quality Control) tubes, establish how close to new they are (selling tubes), in addition to finding good and bad tubes.

Summary:
A Dynamic Mutual Conductance proportional tester will provide a close Gm (proportional) test result but not a laboratory accurate result. Good is within 10% to 15% depending on make and model of tester! The actual proportional voltages applied will vary depending on the circuit design, parts used, factory calibration accuracy, and the actual condition of the circuits in the tester. Additionally the tube being tested will also have an effect on the voltages applied by the tester. The load characteristic of each specific tube tested will load the testers power supplies to different degrees thus changing the amount of DC voltage on the grid. Only certain model testers with DC bias voltage meters allow you to see this and control it more accurately!

As an example: A Hickok tester to test a 6L6 under proportional test values that will measure within the (+/- 10 to 15%) from the nominal 6000 Gm value of a new (ideal) bogey tube would typically require a DC bias voltage of between - 3.0 to -4.0 volts assuming a plate and screen voltage of about 130 volts. This is a range of 1volt in bias and can swing the Gm test result from about 4,900 Gm to about 6,750 Gm based on the tubes actual condition, or characteristics. These values will closely approach the tubes data sheet values based on 250 volts plate and screen at -14.0 volts bias and 72 mA of plate current.

Closing Summary:
Now the final and most important thing to understand is that any tube measured, assuming a properly calibrated tester could have an actual Gm value anywhere between the high and low values based on the percent accuracy of the tester and its actual calibration position in its capable accuracy range. Testers out of calibration can be much further off from the examples used here.

Because of the actual wear on a tester, direct comparison test results are not practical today unless you either know the actual condition of each tester, or have normalized the operating voltages in both testers to the same values. Then if you calibrated both testers at the same time with the same test equipment following the same procedures you will get the same results on both units. So don't think that two testers just serviced and calibrated separately, or even jointly will necessarily produce the exact same test results. If both were new yes, they could within a few percentage points of each other. But when you consider age, usage/wear, and parts tolerance values you would be lucky to get the same test results exactly! Two testers may be able to be brought into the same operating range if the parts will allow it and if you don't mind spending some extra money to achieve the outcome!

In addition related to the usefulness of using a tube tester, any single Gm value test (other than shorts test) may not always tell you if a tube is causing an actual problem in the equipment or not, it does tell you its general condition and its deviation from the ideal nominal specification values. This information with your knowledge and experience will help you establish, if it should be replaced. Evaluating a tube to sell, use, or to purchase for future use is the best application for a tester today as well as locating a generally weak or bad tube. When evaluating a tube there are many characteristics to be considered as well as circuit characteristics and issues as they will effect the tube/circuit inner relationships too!

If you are unclear about anything in this article please feel free to email me at vrte@msn.com for clarity!