TESTING THE 12AU7 ON VARIOUS TUBE TESTERS

INTRODUCTION

Take a batch of tube testers, all in good working order and carefully calibrated following the manufacturer's instructions. Separate them by type—mutual conductance testers in one group, emissions testers in another. Wouldn't you think that if you ran the same tube through all of them, you'd get comparable readings from all of the testers within their respective groups? That would be logical—and wrong. As it happens, each individual tester applies unique conditions to a tube under test, so readings from tester to tester, even on the same model, will *not* necessarily be comparable. Not only that: readings obtained on mutual conductance testers other than laboratory models usually won't match those published in standard tube manuals. Why? Because manuals assume a set of operating conditions that most testers simply cannot duplicate.

Knowing the extent to which readings vary from type to type, brand to brand, model to model, and even across the *same* model would be very helpful, for it would provide a genuine benchmark for comparing the calibration of two or more testers. Testers that are out of calibration cause troubles for tube users, tube sellers, and for technicians repairing tube equipment. In the course of calibrating many tube testers, I collected data on how various models and brands measured the quality of a particular tube of known quality. I realized that presenting my findings would provide such a benchmark, and that is my intent here.

The tube chosen to serve as the standard was an Amperex NOS (new, old stock) 12AU7, obtained from Boca Electromagnetic Lab in Boca Raton, Florida. Ken Powell, owner of Boca Lab (and an electrical engineer and designer whose experience spans the years from the tube era to the latest computers), selected Amperex because this manufacturer's tubes have a deserved reputation for ruggedness and lack of microphonics. Ken first tested the 12AU7 on an RCA WT100A, one of the best lab testers ever made. The Gm results:

Section 1: 2400 micromhos
Section 2: 2480 micromhos

Then it was my turn to check the 12AU7 on the testers listed below. All had been rebuilt, calibrated using the manufacturer's procedures (except Jackson and Precision testers, for which instructions were unavailable), and tested.

The actual readings I obtained, taken directly off the meter, are shown. Some mutual conductance testers read in micromhos, others (and most emissions testers) have a scale with index numbers such as 0 to 100. Readings taken from numbered scales are enclosed in quotes (e.g., "99") and the tester's full-scale reading is provided (FS=130). The "reject point" reading is also provided (RP=50). Roll-chart values for Hickok testers in the 600 family are average tube values. The reject point for these testers was determined by multiplying the average value by .65. Emissions testers are so noted. When more than one tester of a particular model was available, all of the individual readings are shown.

It should be noted that none of these machines are truly lab grade instruments. The Hickok Cardmatics come the closest, but we are still dealing with equipment designed to put good tubes on one side of the bench and bad tubes on the other. Most tube circuits are quite forgiving because new tubes varied so much from brand to brand, so minor variations in tube readings have no significant effect on circuit performance. An individually selected tube had to be used in special cases, but there weren’t many of those. So bear in mind that tube testers are in general not instruments of great precision. All have strengths and weaknesses, testing certain tubes better than others. Try not to apply today’s digital thinking to yesterday’s analog technology and your life with tube testers will be harmonious.

B&K Model 700	“95”/“95”	FS=120	RP=50
B&K Model 707	“99”/“99”	FS=120	RP=50
B&K Model 747	“110”/“105”	FS=120	RP=50
B&K Model 747B			
No. 1	“102”/“100”	FS=120	RP=50
No. 2	“102”/“100”	FS=120	RP=50
No. 3	“110”/“105”	FS=120	RP=50
No. 4	“112”/“110”	FS=120	RP=50
No. 5	“110”/“108”	FS=120	RP=50
No. 6	“113”/“110”	FS=120	RP=50
Eico Model 666 (emissions)			
	“119”/“119”	FS=140	RP=?
Heathkit Model IT21 (emissions)			
	“91”/“91”	FS=100	RP=?
Heathkit Model TC2 (emissions)			
	“82”/“80”	FS=100	RP=?
Heathkit Model TT1A			
No. 1	2480/2580		RP=1420
No. 2	2480/2580		RP=1420
No. 3	2480/2580		RP=1420
No. 4	2400/2400		RP=1420
Hickok Model 123A Cardmatic			
No. 1	“81”/“82”	FS=100	RP=50
No. 2	“78”/“80”	FS=100	RP=50
Hickok Model KS15874-L2 Cardmatic			
	“83”/“84”’	FS=100	RP=50
Hickok Model KS15560-L2			
	2900/2900		RP=?
Hickok Model USM118B Cardmatic			
	“84”/“86”	FS=100	RP=50
Hickok Model 533			
No. 1	2400/2650		RP=1430

No. 2	2500/2620	RP=1430
No. 3	2600/2600	RP=1430
No. 4	2650/2700	RP=1430
Hickok Model 533A		
No. 1	2750/2850	RP=1430
No. 2	2600/2650	RP=1430
No. 3	2700/2800	RP=1430
Hickok Model 536	2650/2750	RP=1430
Hickok Model 539		
No. 1	3200/3200	RP=1950
No. 2	3300/3350	RP=1950
Hickok Model 539B		
No. 1	2800/2900	RP=1950
No. 2	2800/2900	RP=1950
No. 3	3350/3350	RP=1950
No. 4	2600/2650	RP=1950
No. 5	3100/3100	RP=1950
No. 6	3600/3600	RP=1950
Hickok Model 539C		
No. 1	3150/3175	RP=1950
No. 2	3250/3350	RP=1950
Hickok Model 600	2550/2650	RP=1430
Hickok Model 600A		
No. 1	2500/2600	RP=1430
No. 2	2500/2650	RP=1430
No. 3	2650/2700	RP=1430
No. 4	2500/2550	RP=1430
No. 5	2600/2600	RP=1430
No. 6	2600/2600	RP=1430
No. 7	2750/2750	RP=1430
Hickok Model 605	2550/2650	RP=1430
Hickok Model 605A		
No. 1	2550/2600	RP=1430
No. 2	2550/2550	RP=1430
No. 3	2550/2600	RP=1430
Hickok Model 752	2400/2400	RP=1350
Hickok Model 800		
No. 1	2300/2400	RP=1430
No. 2	2600/2650	RP=1430
Hickok Model 6000		
No. 1	2550/2600	RP-1430
No. 2	2550/2550	RP=1430
Hickok Model 6000A		
No. 1	2400/2490	RP=1430
No. 2	2400/2500	RP=1430
No. 3	2550/2600	RP=1430

No. 4	2300/2350		RP=1430
No. 5	2575/2575		RP=1430
Jackson Model 648 (emissions)			
No. 1	“128”/“128”	FS=130	RP=70
No. 2	“129/“127”	FS=130	RP=70
No. 3	“129/“129”	FS=130	RP=70
No. 4	“135”/“135”	FS=130	RP=70
Jackson Model 648-1 (emissions)			
No. 1	“130”/“130”	FS=130	RP=70
No. 2	“130”/“130”	FS=130	RP=70
Jackson Model 648A (emissions)			
No. 1	“127”/“126”	FS=130	RP=70
No. 2	“130”/“135”	FS=130	RP=70
Jackson Model 648S (emissions)			
	“135”/“132”	FS=130	RP=70
Jackson Model 658 (“Dynamic Output”)			
No. 1	“115’/“130”	FS=130	RP=70
No. 2	“115”/“112”	FS=130	RP=70
Jackson Model 658A (“Dynamic Output”)			
	“114”/“110”	FS=130	RP=70
NRI Model 71 (emission type)			
No. 1	“97”/“98”	FS=100	RP=?
No. 2	“95”/“98”	FS=100	RP=?
Philco Model 9100	2500/2700		RP=1430
Precision Model 640 (emissions)			
	“96”/“98”	FS=100	RP=?
Precision Model 660 (emissions)			
	“116”/“118”	FS=120	RP=?
RCA Model WT110A Card Tester			
No. 1	“8.5”/“9.5”	FS=10	RP=5
No. 2	“8.5/“9”	FS=10	RP=5
No. 3	“8.8”/“9”	FS=10	RP=5
No. 4	“9”/“10”	FS=10	RP=5
Sencore MU140			
No. 1	“100”/“98”	FS=120	RP=50
No. 2	“99/“97”	FS=120	RP=50
Sencore MU150			
No. 1	“104/“104”	FS=120	RP=50
No. 2	“103”/“103”	FS=120	RP=50
No. 3	“107”/“107”	FS=120	RP=50

No. 4	“101”/“100”	FS=120	RP=50
Triplett 3413B (emissions)			
	“82”/“81”	FS=100	RP=50
Triplett 3423			
No. 1	2520/2650		RP=2015
No. 2	2550/2600		RP=2015
No. 3	2650/2700		RP=2015
USM TV7U	“103”/“108”	FS=120	RP=56
USM TV7 A/U			
No. 1	“91”/“92”	FS=120	RP=56
No. 2	“92”/“94”	FS=120	RP=56
No. 3	“96”/“97”	FS=120	RP=56
No. 4	“101”/“100”	FS=120	RP=56
No. 5	“108”/“109”	FS=120	RP=56
USM TV7 D/U			
No. 1	“96”/“102”	FS=120	RP=56
No. 2	“98”/“100”	FS=120	RP=56

OBSERVATIONS

Testers within a given family read quite close to each other, especially the seven Hickok 600A’s. Achieving this degree of repeatability between units is obtained by precise setting of the signal voltage. Note also the different reject points for the Hickok 600 series (1430), the 539 series (1950) and the 752 series (1350). Most of us would have thought the 752 and 539 would use the same reject point, but the RP’s for the two are vastly different.

The Hickok 539B model showed greater than expected variation in readings among the different units. I think there are two main reasons. First, construction details vary from unit to unit—more so than with other models. Hickok used different meter types on later testers (round versus square for bias and AC), and the positioning of certain components, such as the electrolytic cap across the quality meter, seemed to change. While component values may have remained essentially the same, even slight alterations in lead dress could affect operation. Indirect evidence of this is Hickok’s increasing use of ferrite beads on its commercial testers (and on the military TV7 models) over time. These beads were an attempt to cure oscillation problems in the testers. This kind of doctoring is hardly an exact science and may not have resulted in total cures. Oscillation in tube testers will generally cause a tube to read much higher than it should due to regenerative feedback. Degenerative feedback is also a possibility, and that would have the opposite effect—it would make a tube read *lower* than it should.

A second and more important reason for the variation may be that the final calibration of 539B and C models is done with a 6L6, a tube that draws relatively high current. This means that for all of the 539B and C units, test results for the 6L6 calibration tube were the same. The final calibration control is in the filament circuit of the 5Y3, which supplies bias and screen voltages for the tester. When testing a 6V6, a somewhat lower-current tube of the same type as the 6L6, the testers all agreed closely: 4300, 4300, 4400, 4300, 4200, 4200, 4500, and 4500. (The last two readings were for a different tube than was used to test the other six testers.) Since the dual-triode 12AU7 does not have a screen, the calibration control might have a different effect. In other words, when this control is set to *increase* the reading for the 6L6 calibration tube, the same setting could cause the readings for a 12AU7 to *decrease*, since the tube has no screen. The interactions of all of the tube voltages is complicated by the fact that they are pulsating DC. Why Hickok did not anticipate the effect of this control is puzzling.

This is the best explanation I can offer for the observed variation in 12AU7 readings. Is this a practical problem? Probably not. The stated reject point for a 12AU7 on the 539B and 539C charts is 1950 micromhos. Even the lowest reading observed for any tester (2600 micromhos) was far above that.

A POSSIBLE SOLUTION?

In consulting with an expert on Hickok calibration, it was suggested to me that certain unspecified modifications may be required to get 539's to calibrate more closely for all tube types. I don't feel that end users should have to make such modifications, and that such work should have been done at the factory. A more practical solution is to adjust the bias setting used when testing a critical tube.

For example, let us assume that the correct reading for our 12AU7 benchmark tube is 3200 micromhos, but your tester reads markedly lower or higher. A minor change in bias setting will deliver the desired reading. To illustrate, I tested a 539C with the Amperex 12AU7. Here's how Gm varied with different bias meter settings.

Bias meter setting	Gm
-2.8 VDC	3500
-3.0 VDC	3250
-3.2 VDC (chart setting)	3200
-3.4 VDC	3150
-3.6 VDC	3000
-3.8 VDC	2950
-4.0 VDC	2800

It is obvious that small changes in bias settings can easily correct for the triode test variations observed. Setting the bias meters on 539's with great precision is difficult anyway, and some tubes, such as the 6CB6, are far more affected by small bias changes.

The opposite situation occurs with smaller Hickok testers like the 600A. These testers agree very closely when testing the 12AU7, but on high-current tubes they can differ by more than 10 percent. A suggested reason for this is individual variation in the transformers used. Some transformers sag more than others under heavy load. This is particularly true of filament windings.

PRACTICAL APPLICATIONS

This article shows the range of results that can be obtained in testing a single tube. It should also furnish a means of comparison between two testers of different types. If you test a tube on a properly calibrated Hickok 600A and it reads 2500 micromhos, you can send the tube to a friend with a 533A and expect a reading that is well within 10 percent of 2500. On the other hand, if you wanted to check a model 539, a 6L6 should be chosen, because the 539 family is standardized for that tube. Other tube types, particularly triodes, may not give comparable results. Also, it is quite clear that readings for a 12AU7 cannot be compared across the 600, 539, and 752 families.

The Amperex 12AU7 I used had very strong emission, and should test that way on any emissions tester. So test results from emissions testers are comparable, at least when testing low-current tubes. Strong cautionary note: testing high-current tubes like a 5U4 would *not* be a good way to compare emissions testers. At first glance, it would seem that a rectifier would be ideal, since emissions testers essentially measure a tube's capability to deliver a specified current. But the transformers in many small emissions testers can't deliver sufficient current for a valid test. These small testers will tend to read nearly all high-current tubes as good. When using an emissions tester, you can be fairly certain that a tube that tests weak is bad. You cannot be as sure when a tube tests strong that it is good. The tube could just be strong enough to pass all the current the tester is capable of delivering.

Each family of tube testers has unique characteristics. Testers like the Sencore MU140 and MU150 are family members; the test results they yield may be directly compared. The B&K 700 and 707 are also family members, yielding comparable results. The Hickok 600A, 533A, and 605A form yet another family. The most valid comparisons are among members of the same family, compared with an appropriate tube. In selecting a tube to be used for comparison, both current and type are important factors.

For most of the testers listed, the 12AU7 is a useful tube to compare calibration. For other testers, like the 539, a 6L6 would be best. In comparing emissions testers, a low to medium current tube is suggested like a 12AU7 or a 6V6. High-current rectifiers, like a 5U4, would be a poor choice.

There are two additional factors to consider when comparing tube tester readings. On testers such as the Sencore and B&K models, there is no manual adjustment to compensate for AC line voltage variation. Differences in AC input voltage to these testers are compensated for by circuits within the testers themselves. These systems are imperfect, and if you vary the AC input to the testers from 110 volts to 125 volts, you will observe a change in quality reading for the tube under test of about 5 to 10 percent. So for the most valid comparison on these models, the AC input voltage must be held constant. With Hickok (and perhaps other brands as well), an additional factor to consider is how long the tester has been turned on. Many models, like the 539 and 752, are not temperature stable. If you test a tube when the unit has been on for 10 minutes and test the same tube 2 hours later, your results will probably be significantly different. For checking calibration and making other critical tests involving these models, a minimum half-hour warmup is advisable.

I hope this article provided useful information about a poorly understood subject. It may save some of you the expense of having your tester calibrated. Others may find that they do need to service their tester. Armed with this knowledge, we are in a better position to help each other and to better understand the strengths and limitations of the testers we use.

Chris Haedt
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Notes:

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