More on Testing Tubes, Hickok and Beyond

"The World of Triplett"

For

Radio and Tube Collectors

Paul K. Hart

MAARC RadioActivity 2019
Beltsville, MD
June 28, 2019

Presentation Organization

- **Reasons for testing vacuum tubes**
- **Misinformation**
- **Development of rigorous testing capability**
- **Hickok's "genius circuit" - Dominance**
  - **Focus on the TV-7**
- **Other approaches - Triplett 3423, 3444, 3444A**

Tube Testers and Classic Electronic Test Gear

by

Alan Douglas

- **An invaluable wide ranging review of tube testers**
- **Additional information on other test equipment**
- **Much information on the characteristics of various testers**
- **An enduring resource**
- **Reprints are available at reasonable prices**

Tube Lore
Ludwell Sibley

- **Published in 1996**

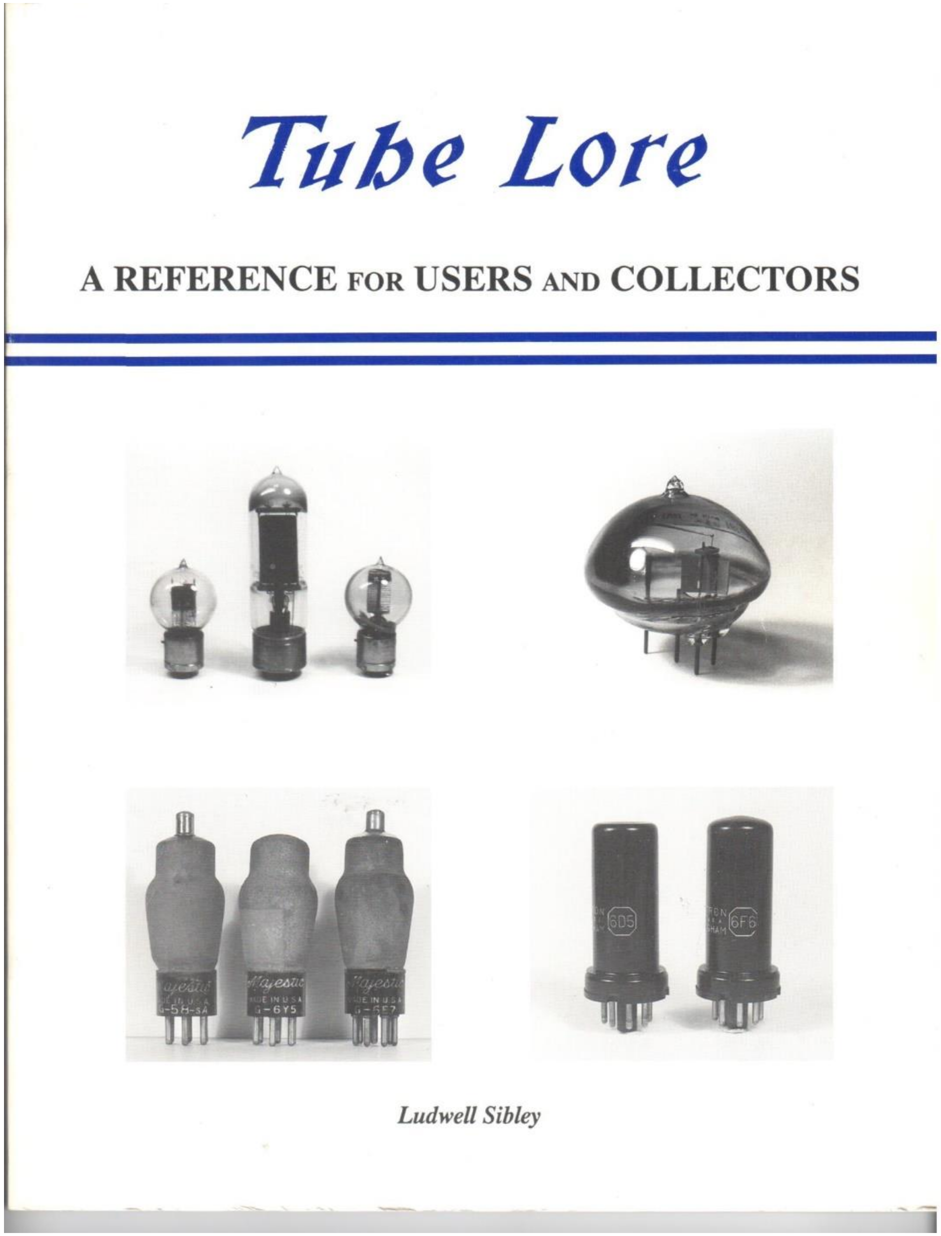
  Three Addenda have been released

- **Promised new release in the works Tube Lore II**

- **Sibley is the President of the Tube Collectors Association**

  "History-Preservation-Application"

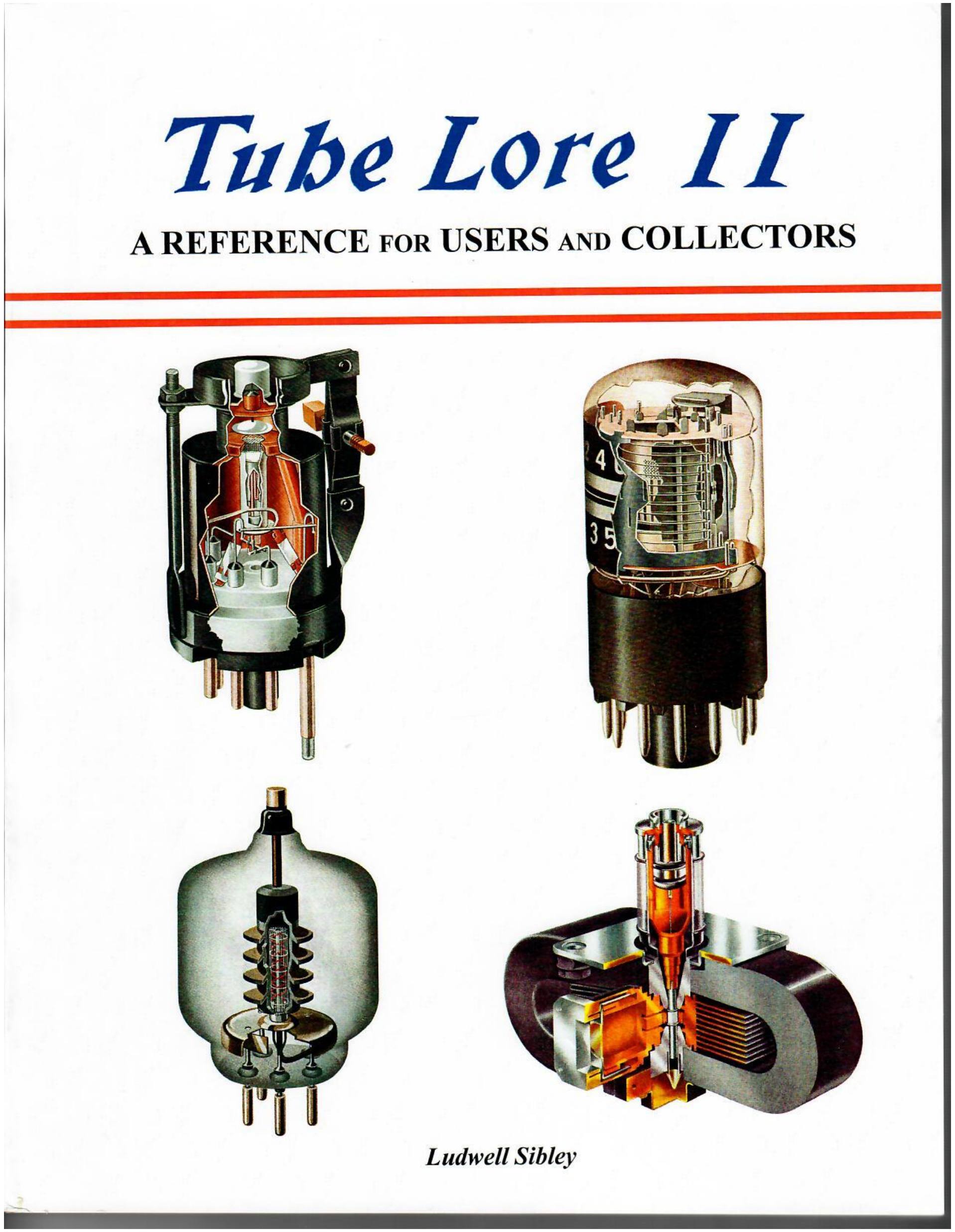
- **One of the rarest of references for good reason. An invaluable source for information on vacuum tubes, their use and history.**



And Now
Tube Lore II

Sibley's milestone reference book, Second Edition.

Accompanying disc includes info on specialized tubes and date codes.



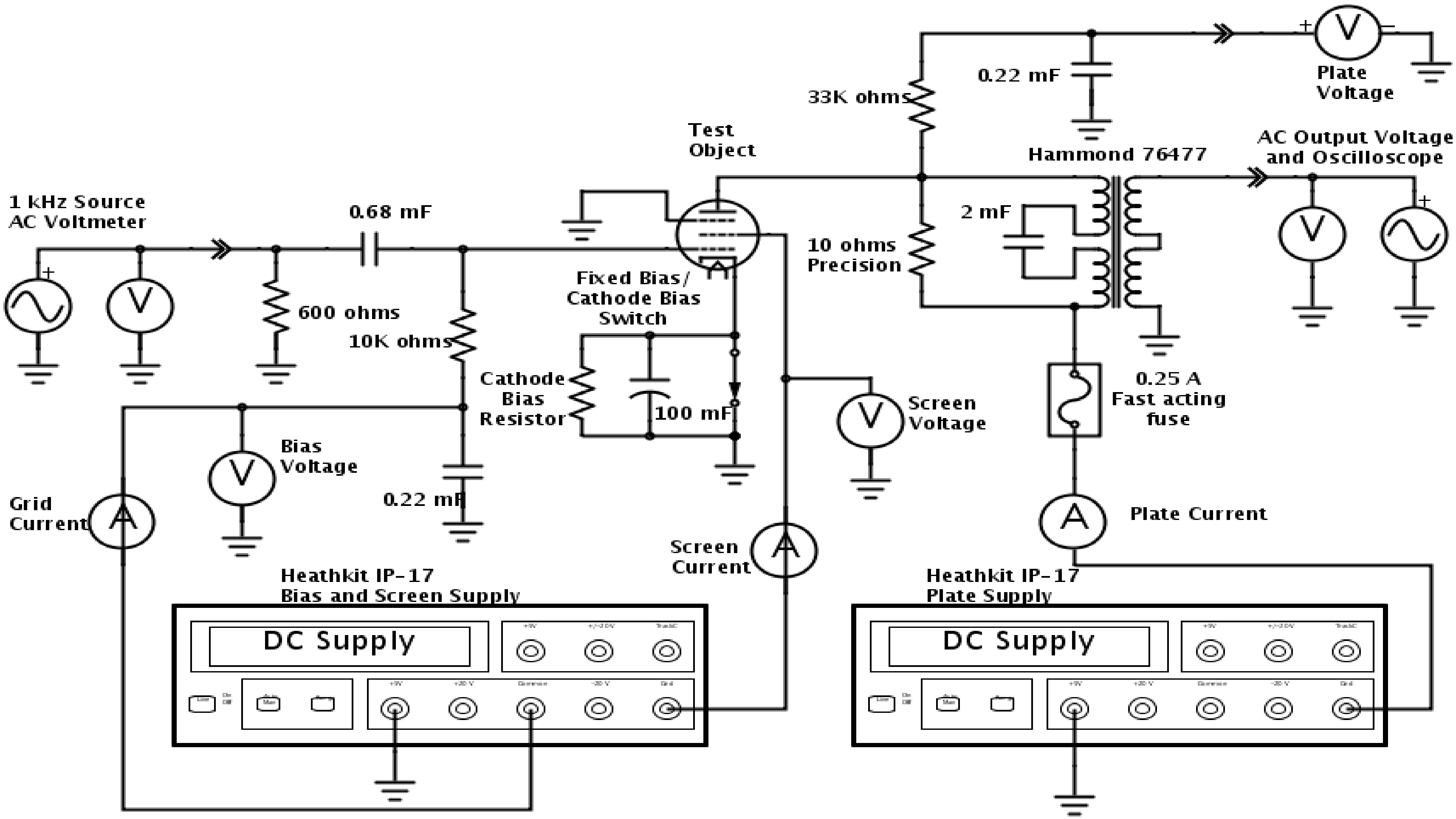
Need to Test Vacuum Tubes

- **Discover the condition of a tube**
  - **Wide variety of conditions that can be tested**
  - **Rigorous testing to the manufacturer's specifications is difficult and rarely done**
  - **Does it matter?**
- **Does the tube accomplish its necessary function?**
- **Basic test capabilities available on most emissions or surrogate testers**
- **Playing the numbers game with test results, usually transconductance, requires sophisticated capabilities**

Developing a Basis for Evaluation

- Develop the ability to measure transconductance of a vacuum tube in accordance with the engineering definition of transconductance.
- A "no excuses" tester to measure tube performance using the mathematical definition of transconductance – the change in plate current of a tube divided by the change in grid voltage
- In practice, the AC signal method is most practical – as opposed to complex bridges, or delta measurements
- Test conditions specified by the manufacturers must be maintained
- RCA shows how to do it, Alan Douglas shows it in his book-page 10, high end laboratory testers do it. Some high end testers do it – no new science

Schematic of Lab Tester



Jagundo Tester

MAARC RadioActivity 2014

The Ubiquitous Calibration Tube Used by Hickok The 6L6

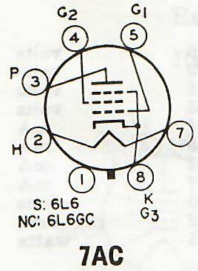
- ✓ A huge number were made
- ✓ Durable, Inexpensive
- ✓ Many sources offer to sell you a calibration 6L6
- ✓ Each one has its own idea of valid calibration
- ✓ Different tubes track differently under different test conditions

Tube Manual Listing for the 6L6

- The 6L6 is the tube type chosen by Hickok as its calibration tube.
- Transconductance values are different for each of the three specified test conditions.
- Transconductance does not precisely track plate current.
- The power dissipation limit for the 6L6 is 19 watts. Increased to 30 watts for the GC.
- Challenge in testing: A "hot" tube may draw enough plate current to exceed the dissipation rating. Tester must have the capability to deliver the power required.

6L6
6L6GC

BEAM POWER TUBE



Metal type 6L6 and glass octal type 6L6GC are used in the output stage of audio amplifying equipment, especially units designed to have ample reserve of power-delivering ability. **Outlines section,** 4 and 19D, respectively; require octal socket. These tubes, like other power-handling tubes, should be adequately ventilated. Type 6L6GC can be used in place of type 6L6 and may be supplied with pin 1 omitted.

Heater Voltage (ac/dc)		6.3	volts
Heater Current		0.9	ampere
Heater-Cathode Voltage:	6L6	6L6GC	
Peak value	±180 max	±200 max	volts
Average value	—	100 max	volts
Direct Interelectrode Capacitances (Approx.):			
Grid No.1 to Plate	0.4*	0.6	pF
Grid No.1 to Cathode, Heater, Grid No.2, and Grid No.3	10*	10	pF
Plate to Cathode, Heater, Grid No.2, and Grid No.3	12*	6.5	pF

* With pin 1 connected to pin 8.

Class A_1 Amplifier

MAXIMUM RATINGS	6L6 Design-Center Values	6L6GC Design Maximum Values	
Plate Voltage	360	500	volts
Grid-No.2 (Screen-Grid) Voltage	270	450▲	volts
Plate Dissipation	19	30	watts
Grid-No.2 Input	2.5	5	watts

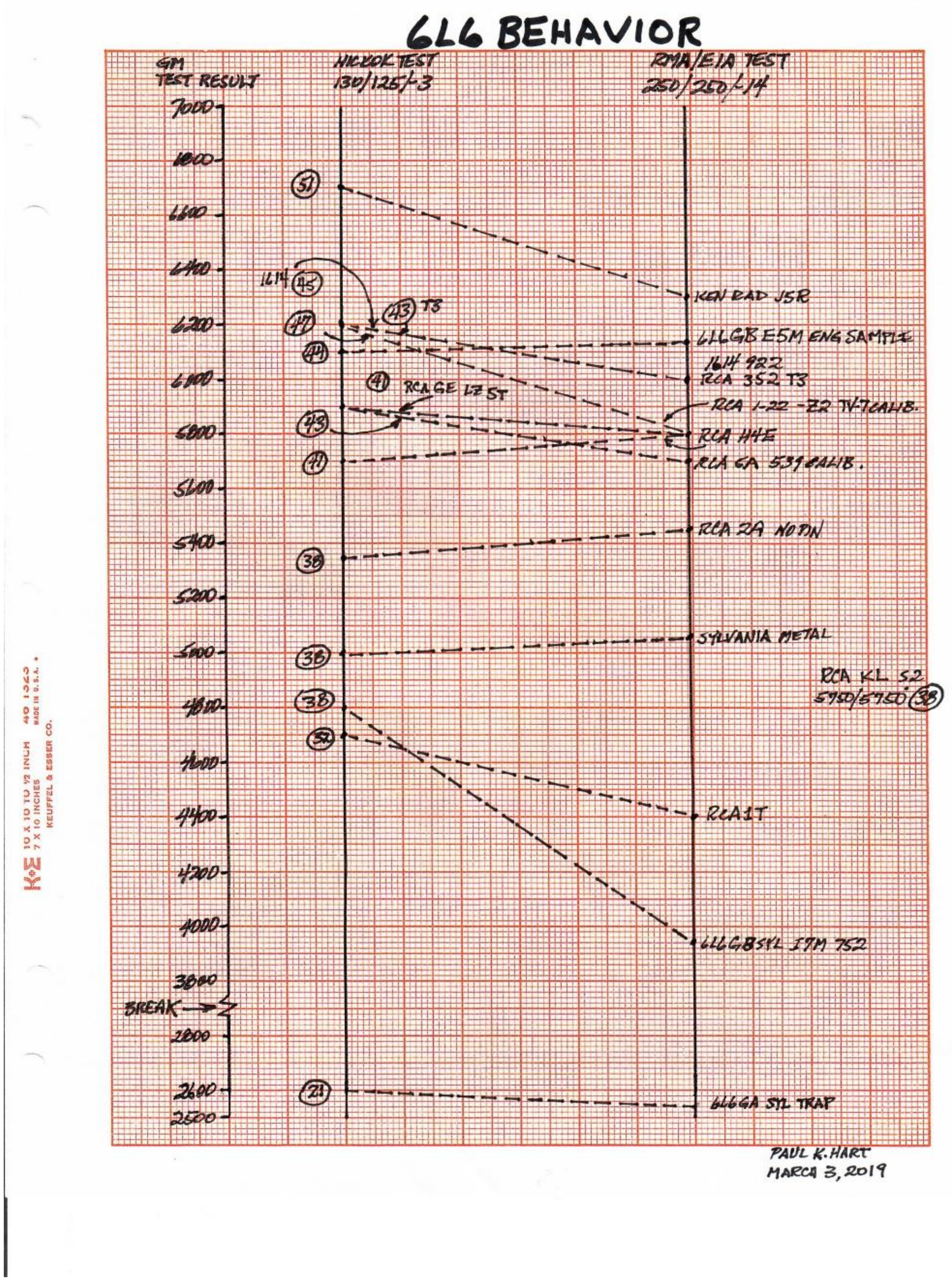
TYPICAL OPERATION				
Plate Voltage	250	300	350	volts
Grid-No.2 Voltage	250	200	250	volts
Grid-No.1 (Control-Grid) Voltage	—14	—12.5	—18	volts
Peak AF Grid-No.1 Voltage	14	12.5	18	volts
Zero-Signal Plate Current	72	48	54	mA
Maximum-Signal Plate Current	79	55	66	mA
Zero-Signal Grid-No.2 Current	5	2.5	2.5	mA
Maximum-Signal Grid-No.2 Current	7.3	4.7	7	mA
Plate Resistance (Approx.)	22500	35000	33000	ohms
Transconductance	6000	5300	5200	µmhos
Load Resistance	2500	4500	4200	ohms
Total Harmonic Distortion	10	11	15	per cent
Maximum-Signal Power Output	6.5	6.5	10.8	watts

▲ In push-pull circuits where grid No.2 of each tube is connected to a tap on the plate winding of the output transformer, this maximum rating is 500 volts.

18W 14.4W 18AW

Behavior of Samples of 6L6 Tubes

- **Actual test readings of 12 samples of 6L6 tubes**
- **Tested under Hickok test conditions 130/125/-3V and Industry specified conditions of 250/250/-14V**
- **Scale from 2500-7000 are actual gm readings – note scale break at 2900.**
- **Circled numbers are test scores from a calibrated TV-7D/U**



From the "Tube Collector", Tube Collectors Association December 2001, Vol. 3, No. 6 page 7

www.tubecollectors.org

RCA PARAMETER LIMITS FOR NEW TUBES

Jerry Vanicek once suggested a check of the Dowd-RCA Archive for the official limits on tube performance. The following figures are from Standardizing Notices of '30s vintage (for the '20s oldies listed) and of '60s vintage for the later audio tubes.

These are, of course, limits for **new** tubes. As Bill Condon's article points out, they do not define "good" or "bad" for used tubes. Dealing with used goods, we have to allow for some slumping in use, which raises the question of how tube-tester makers defined "GOOD-?-BAD" readings. As for life tests, RCA's tests for civilian tubes relied on a simple power-output test ("expect 'x' watts' output after 500 hours") rather than specifying Gm or plate current.

The "bogie" figures for a tube might match the corresponding values in, say, the RC-15 manual, under the same test conditions (e. g., for the 71A and 6L6) but usually differed slightly. The factory limits for Gm might be symmetric about the bogie (for the 12A, 24A, and 27, say) but more often were not. (There's probably nothing in nature that would require symmetric limits.) An excessive Gm would be a worry to the factory: it might indicate a grid dangerously close to the cathode. The "customer" limits presumably allow for some knocking-about, tester error in the field, and a few hours of use. - LAS

	TRANSCONDUCTANCE (μS)					PLATE CURRENT (mA)					
Type	Cust. Min.	Fact. Min.	Bogie	Fact. Max.	Cust. Max.	Cust. Min.	Fact. Min.	Bogie	Fact. Max.	Cust. Max.	Measured at $E_p / E_{g2} / E_c$
10	-	1350	1600	1900	-	13	18.5	24	-	-	425 V / - / -35 V
12A	-	1300	1600	1900	-	4.5	6.2	8.5	-	-	135 V / - / -9 V
22	-	300	350	425	-	1.2	1.7	2.3	-	-	135 V / 45 V / -1.5 V
24A	900	950	1100	1250	1300	2.8	3.1	4.2	5.0	5.3	250 V / 90 V / -3 V
26	-	875	1075	1225	-	4.0	5.5	7.0	-	-	135 V / - / -9 V
27	815	850	1000	1150	1185	3.1	3.5	5.2	6.9	7.3	250 V / - / -21 V
40	-	300	400	525	-	0.40	0.45	0.90	-	-	135 V / - / -1.5 V
45	1550	1650	2100	2500	2550	20	22	30	38	40	250 V / - / -50 V
50	1550	1700	2100	2500	2550	40	42	55	68	70	450 V / - / -80 V
71A	1450	1550	1700	1850	1950	14.0	15.0	20.0	25.0	26.0	180 V / - / -40.5 V
199	-	350	425	570	-	1.6	2.4	3.5	-	-	90 V / - / -4.5 V
201A	-	600	725	825	-	-	1.7	2.4	3.2	-	90 V / - / -4.5 V
2A3	3200	3450	4000	4550	4800	22.5	28.0	40.0	52.0	57.5	300 V / - / -60 V
6BQ5	8300	8600	11,300	14,000	14,300	36	37	48	59	60	250 V / 250 V -7.3 V
6L6	5400	5550	6000	6450	6600	60	62	72	82	84	250 V / 250 V / -14 V
6L6GB			Same as for 6L6			62	64	72	80	82	Same as for 6L6
6L6GC	5300	5400	6000	6600	6700	58	60	72	84	86	Same as for 6L6
6V6GT	3500	3600	4100	5400	5500	33	34	45	56	57	250 V / 250 V -12.5 V
5881	5500	*	6100	*	6700	65	*	75	*	85	Same as for 6L6
7027A	5300	5400	6000	6900	7000	58	60	72	84	86	Same as for 6L6
6973	3800	4000	4800	5600	5800	57.5	60	65	-	-	250 V / 250 V / -15 V

* 5881 was a purchased type; no manufacturing limit. Figures unavailable for 6550, another purchased type.

Two Triplett Testers

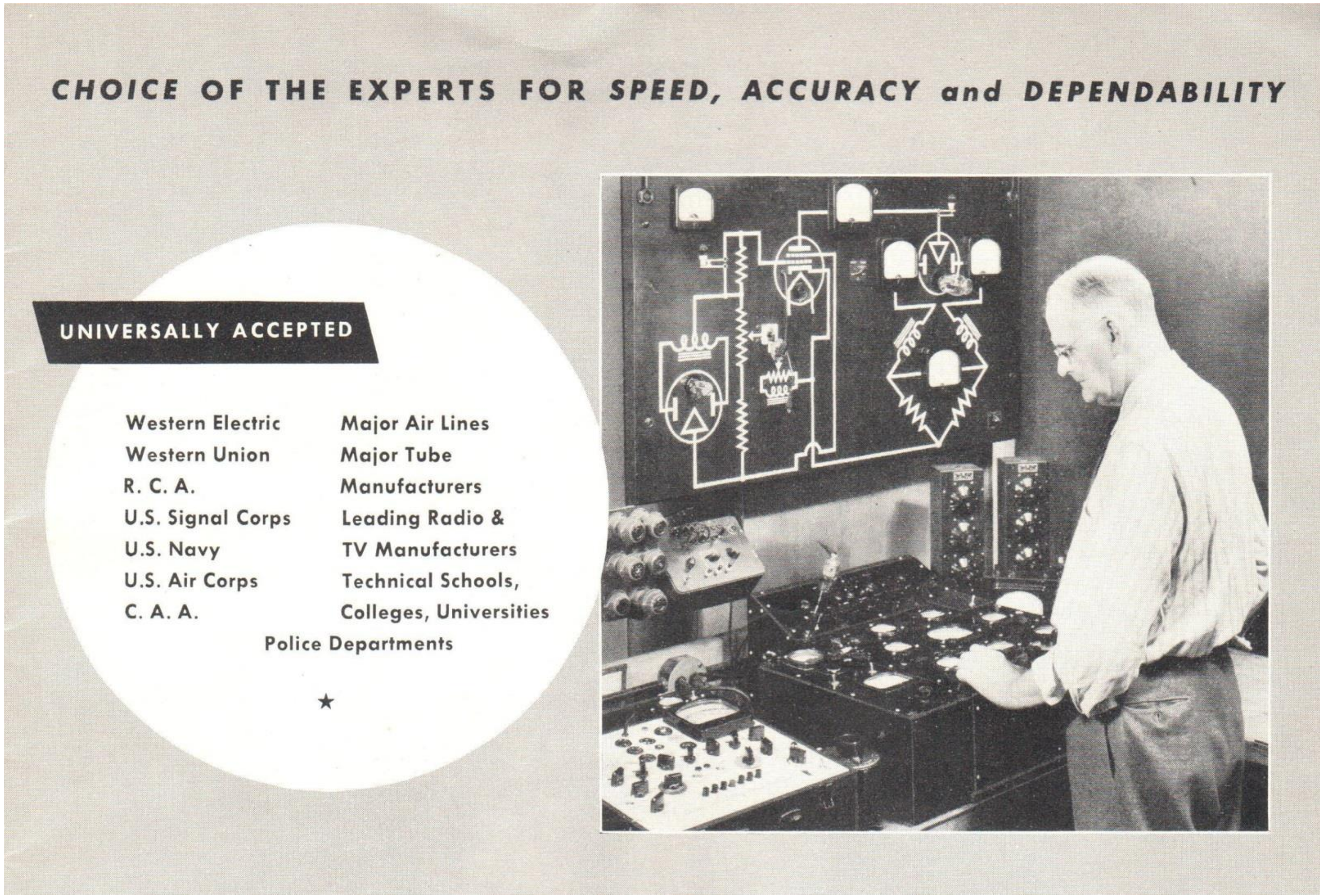
2413 Emissions Tester (1946)

3423 Triplett's first gm tester (1953)
"Proportional Transconductance"

Hickok TV-7/U First Production Version (1953)

Note the skirted dials on the Bias and Shunt controls. Later variants had number settings engraved in the panel. Except for the first Navy run by Hickok in 1952, all U's were made by Supreme Instruments, company bought by Hickok in 1956.

The Hickok "Genius Circuit" and its Legacy



Is this Job Barnhart?

Simplified TV-7 Gm Test Circuit
From military manual, pg. 16

U.S Department of the Army, Technical Manual TM 11-6625-274-35 dated 30 June 1960 to Change 5, 30 March 1976.

For brief review and “package” discussion.

Note provision for adjusting both sides of the bridge for calibration.

Is operation as clean and simple as the description implies?

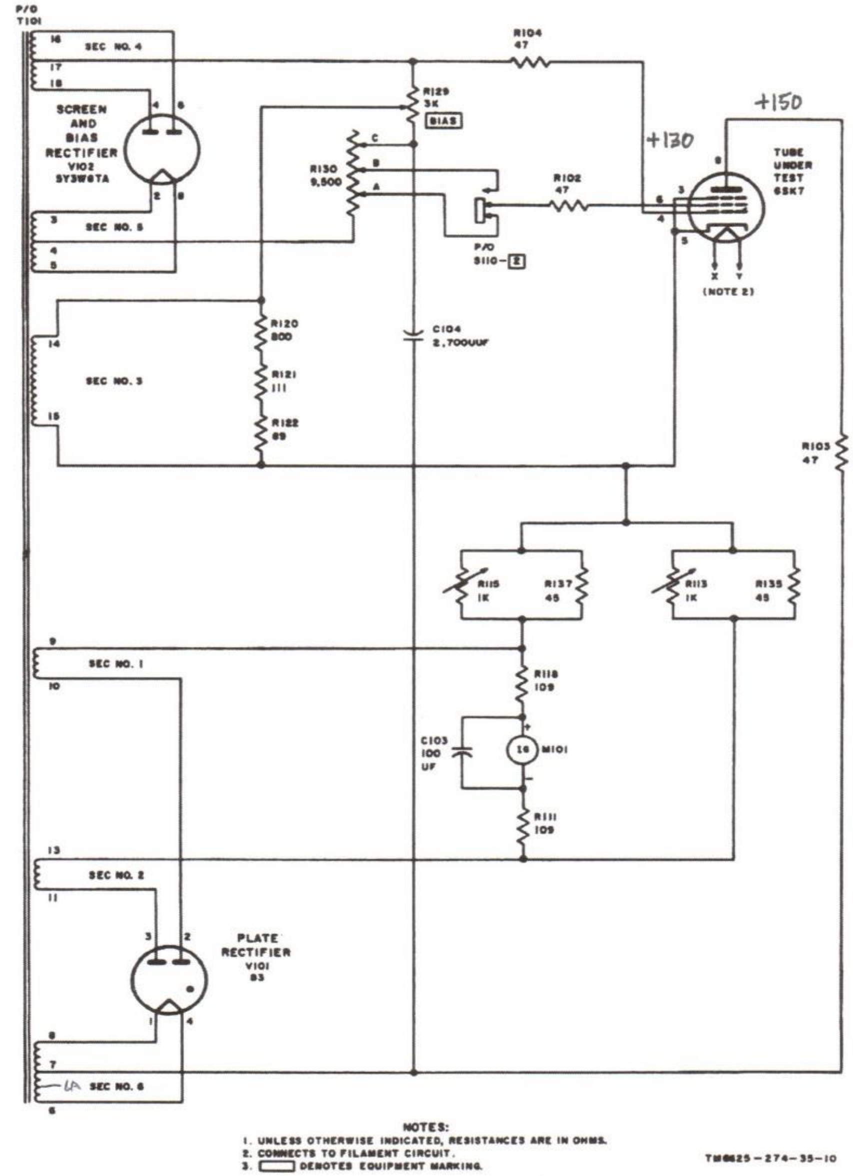


Figure 11. Simplified mutual conductance test circuit, TV-7D/U.

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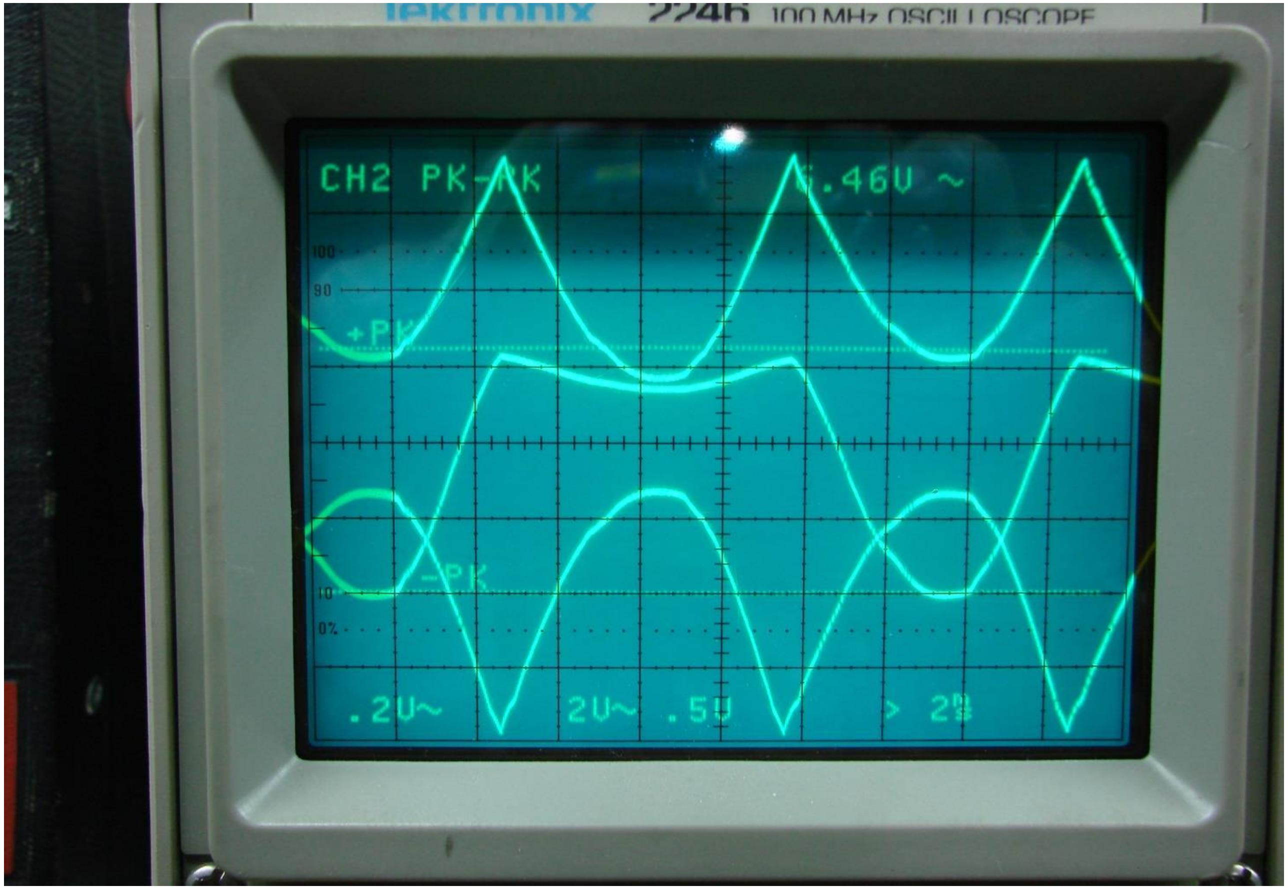
Three Channel view – one side of the bridge, Hickok 539B

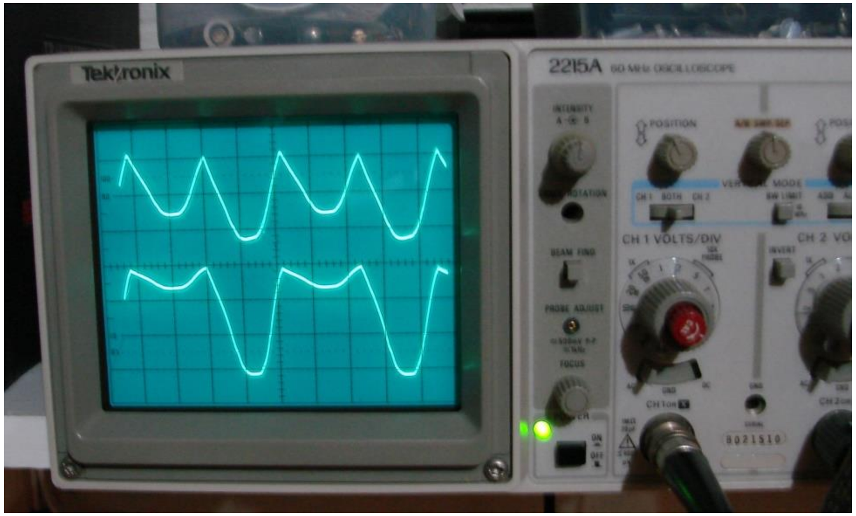
- **Top trace is a combination of the input signal and chopped AC bias signal.**

- **Second waveform is the current waveform on the cutoff side.**

- **Third waveform is the plate of the tube, showing the full wave character of the rectifier.**

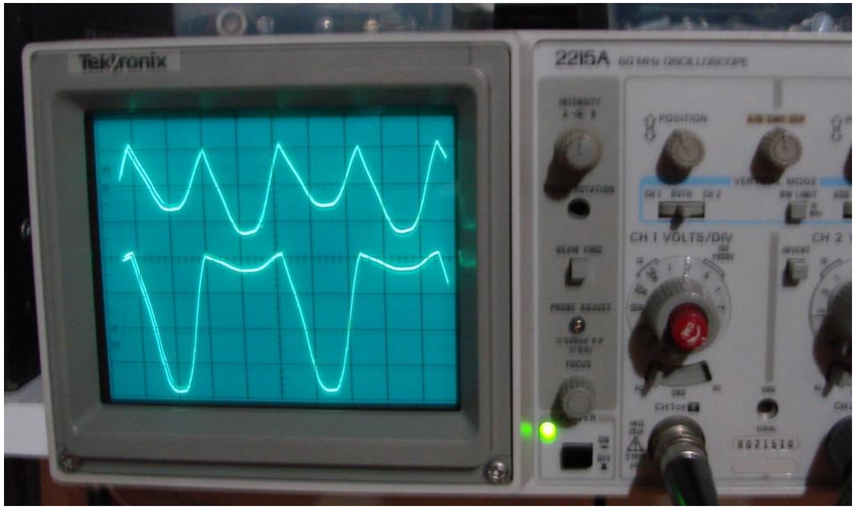


Realities of the Bridge (TV-7)
Testing a 6L6 1V sig, -3.1V bias



R113 side of the bridge 863mV

First negative swing finds no return path and is cut off. The next (more negative) swing finds return path and results in significant current signal.



R115 side of the bridge 668mV

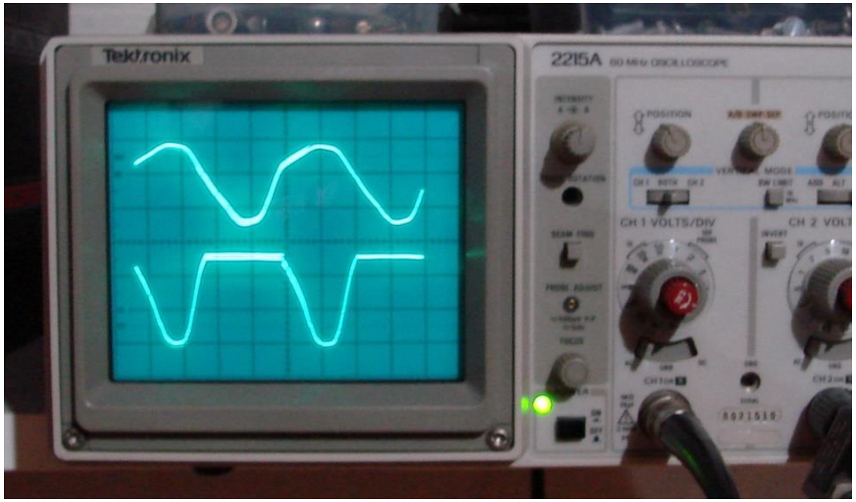
First negative swing finds return path and results in significant current signal. The next (more negative) swing finds no return path and is cut off.

Realities of the Bridge (TV-7)

Testing a 6F5 (1/2 12AX7) 5V sig, -1.1V bias

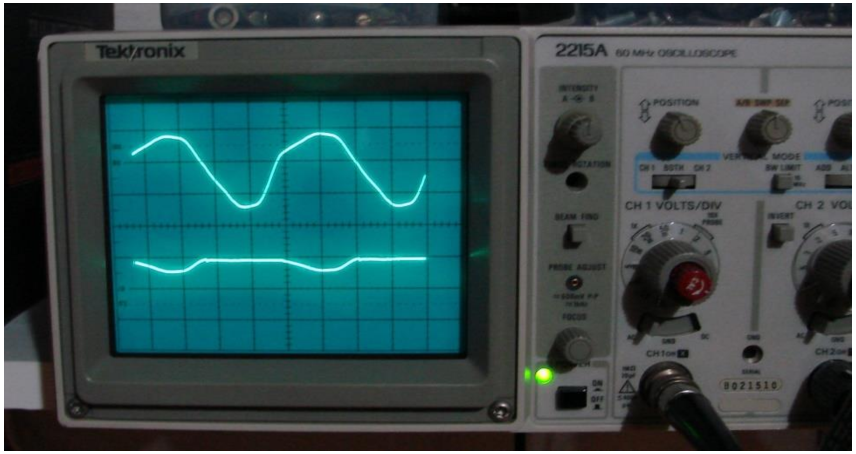
R113 side of the bridge   214mV

The positive swing of the test signal/grid bias saturates the tube and allows a large current flow. The negative half cycle cuts the tube off.



R115 side of the bridge 4 mV

The positive swing of the test signal/grid bias saturates the tube, but there is no return path, little current flows. The negative swing cuts the tube off. As a result, very little current flows in this side of the bridge.



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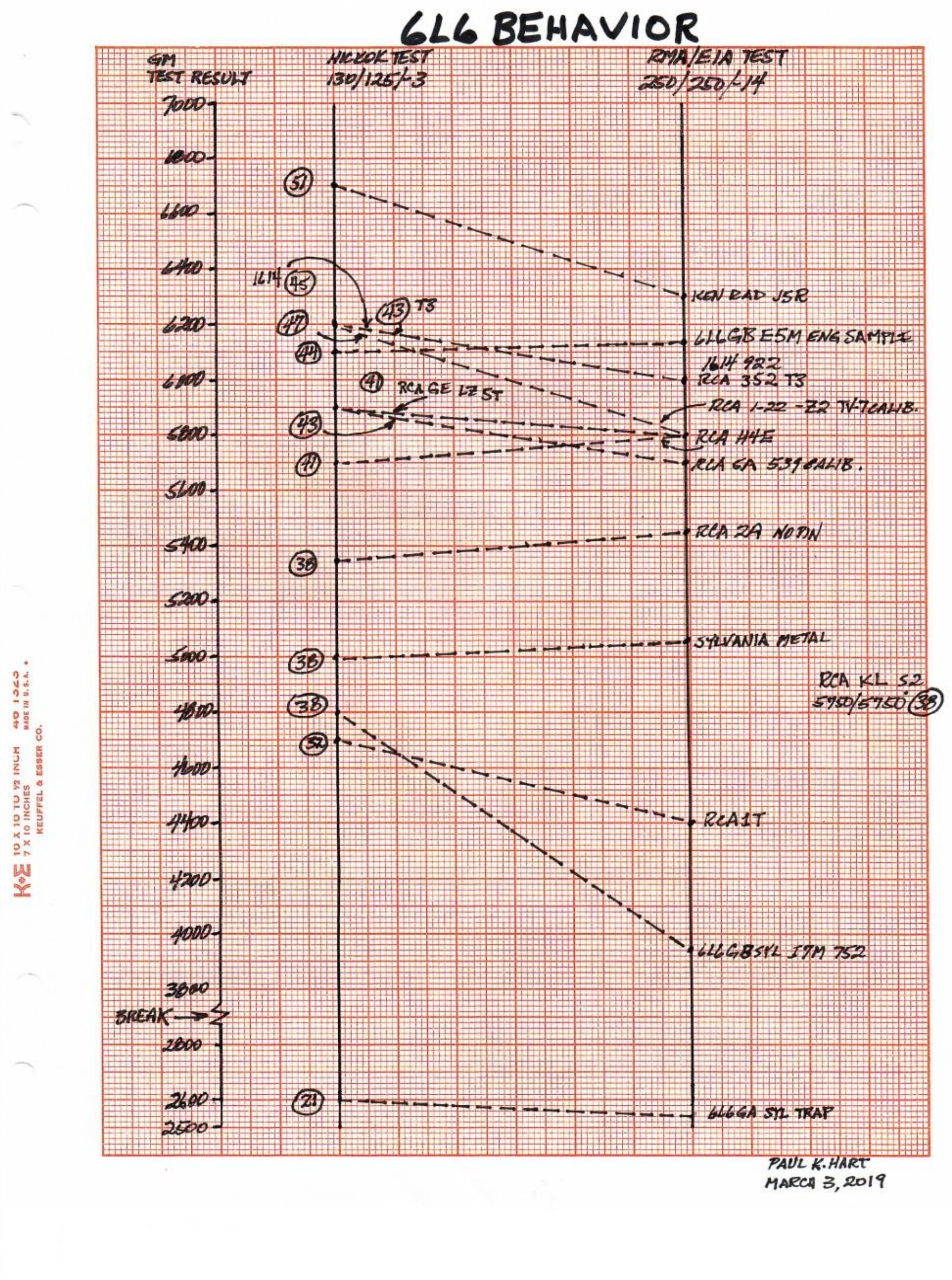
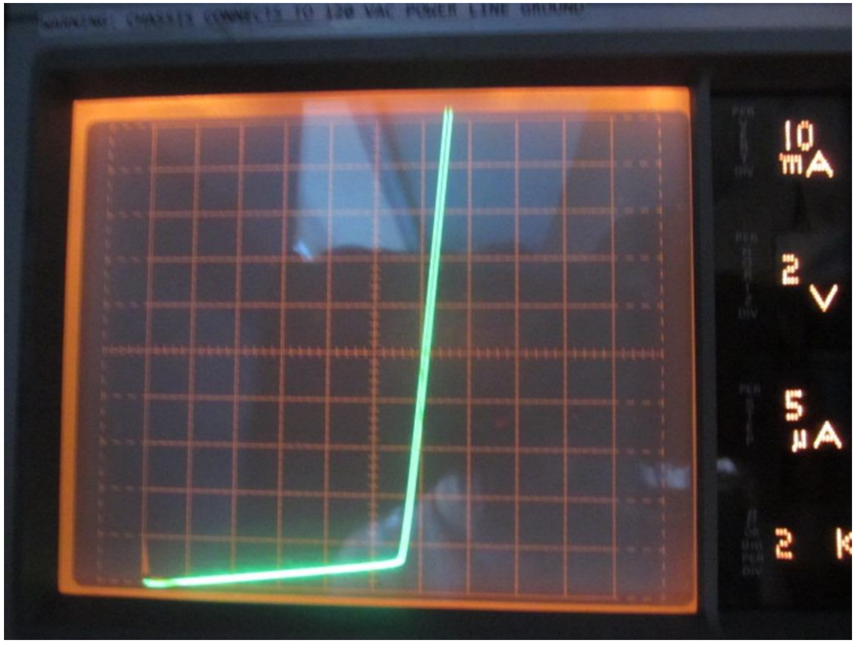


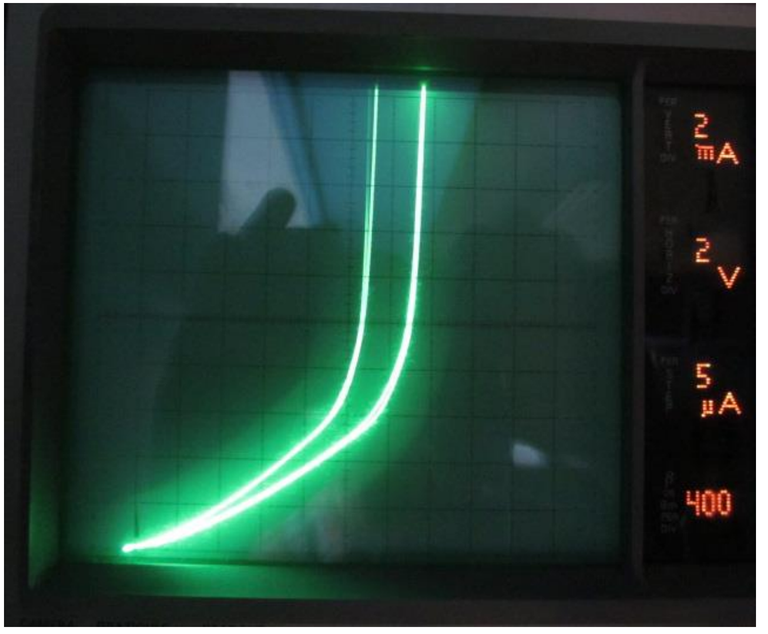
83 Rectifier Observations

Sweep photos courtesy of Mike Higgins

Clean knee of SS replacement

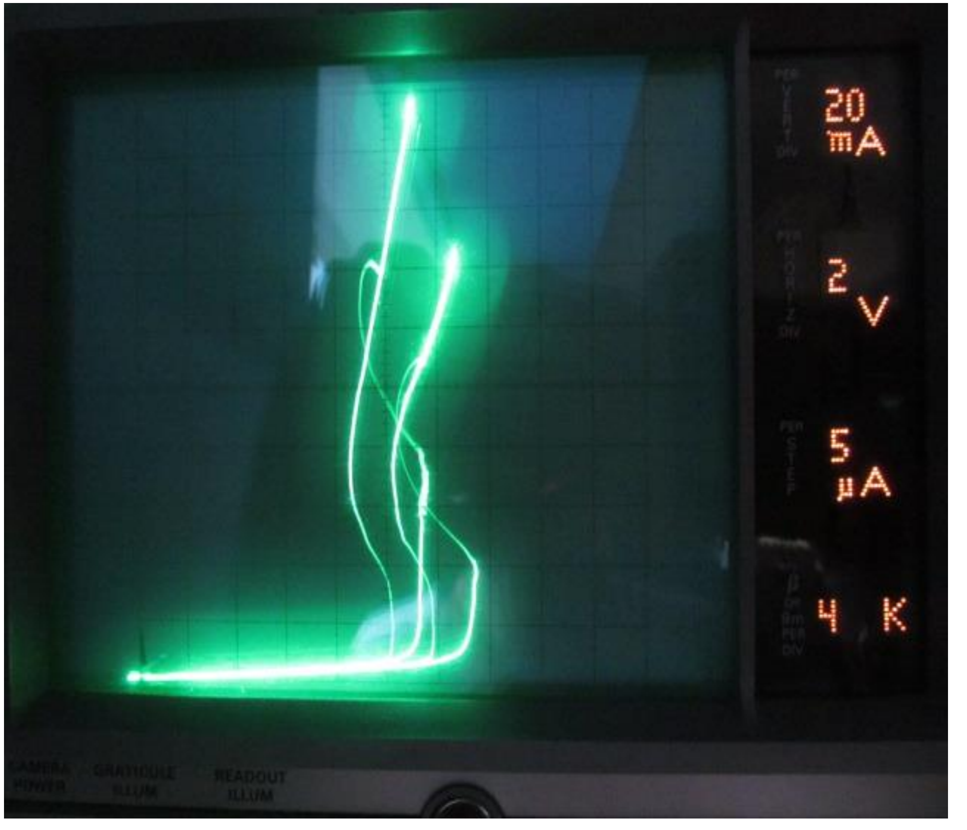


Normal knee, 83 tube



Full Scale Sweep of Aged 83

- Sweep shows erratic nature of the tube behavior.
- Is this the cause of observed irregular results in Hickok testers?
- Amateur radio operators experience with "hash" from mercury vapor rectifiers
- More study/experiment required.
- No question about behavior of the SS83 replacement.



Sweep photo courtesy of Mike Higgins

Common Characteristics of all Hickok Testers

- **Chopped AC was used for testing - 150V plate**
- **Screen voltage – 135V was shared with bias – all chopped AC**
  - **WECo versions had DC bias/did not share chopped screen voltage**
- **Signal voltage is full cycle 60 Hz**
  - **Many testers apply high test voltages**
  - **Leakage from filament can be a problem**
- **Transconductance inferred by reading difference between two legs of the bridge**
- **Specially selected 6L6 tubes required for calibration**
- **No electrolytic capacitors were needed**

Perspectives on Calibration The issue of Calibration Tubes

- **Hickok has left many clues as to calibration techniques using calibration tubes.**
  - **Bridge adjustments specified in TV-7A,B,D series**
  - **Calibration instructions for 6000 and earlier models use shunt pot mismatch and 6L6 for gm calibration**
  - **Adjustments in rectifier cathode returns for calibration**
  - **Not aware of any Hickok procedure to balance the bridge**
- **Use of AC surrogate as virtual tube**
  - **Recommended test specifications for many testers**
  - **Tests only the gm bridge – great influence of bias conditions not taken into account with AC surrogate**
  - **Conclusion: Calibration tubes are required**
  - **No original tubes available creates dilemma**
  - **Many “calibration tubes” available on eBay**

Calibration Tube Dilemma

- **Each type of tester is set up differently**
- **How do you know if the spools have maintained their original values?**
- **Hickok closely guarded their standard test tubes**
- **If you could find one of the original calibration tubes now, you couldn’t trust it**
- **New calibration tubes must be created**
  - ➢ **Understanding of 6L6 behavior and laboratory test facility makes it possible**

Evolution of Triplett 3423

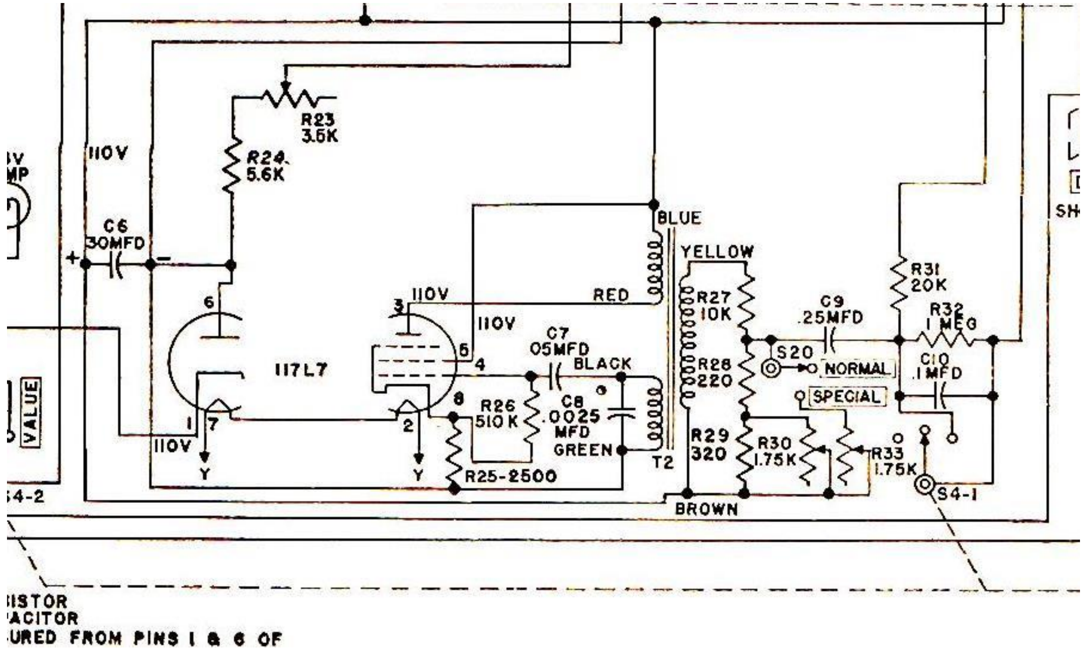
Under Serial 3001
Traditional style black frame meter
"Dished" knobs
Leakage test added above Serial 2254

Serial 3001 and above
Newer style clear frame meter
Later "bar" knobs

Both versions identical electrically in the gm test - "Proportional Transconductance"
Because of the meter and leakage test, the "sweet spot" is 2255 to 3000

Power Supply and Oscillator

- Original units were provided with plastic line plugs with two fuses, one for each side of the line.
- Line connection to the filament creates a safety hazard and leakage potential between the filament and cathode of the pentode section
- Modification: Substitute a silicon diode for the vacuum tube rectifier and a 6K6 for the pentode section of the 117L7
  - Requires installation of a 6V filament transformer
  - Greatly reduces power dissipation
- These changes allow installation of a three wire cord, grounding the chassis and installation of a fuse on the panel.

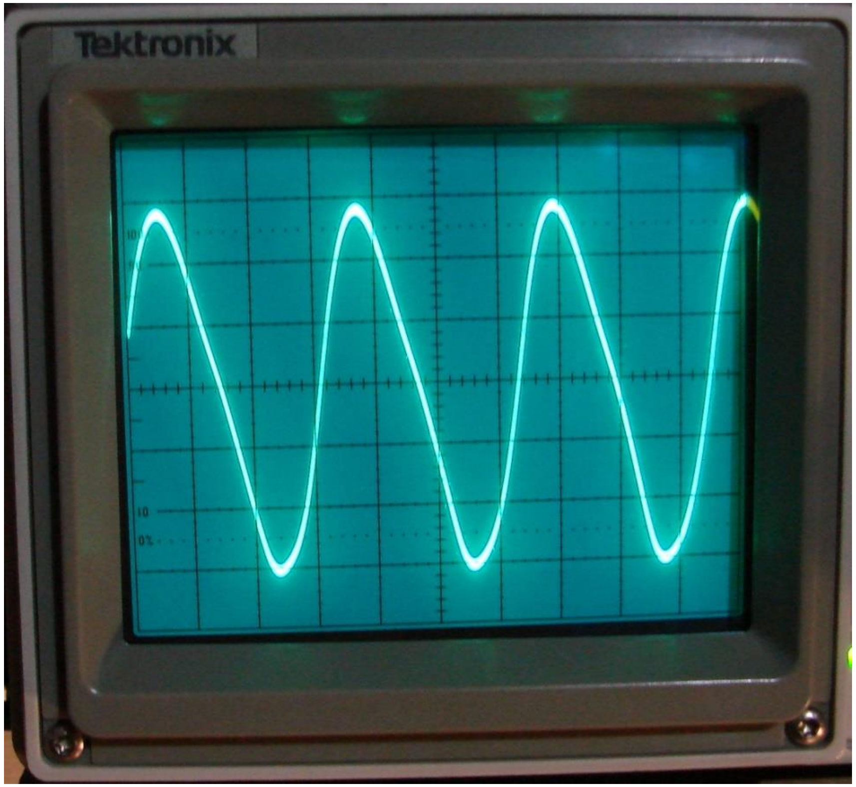


Power supply and Oscillator area of Schematic

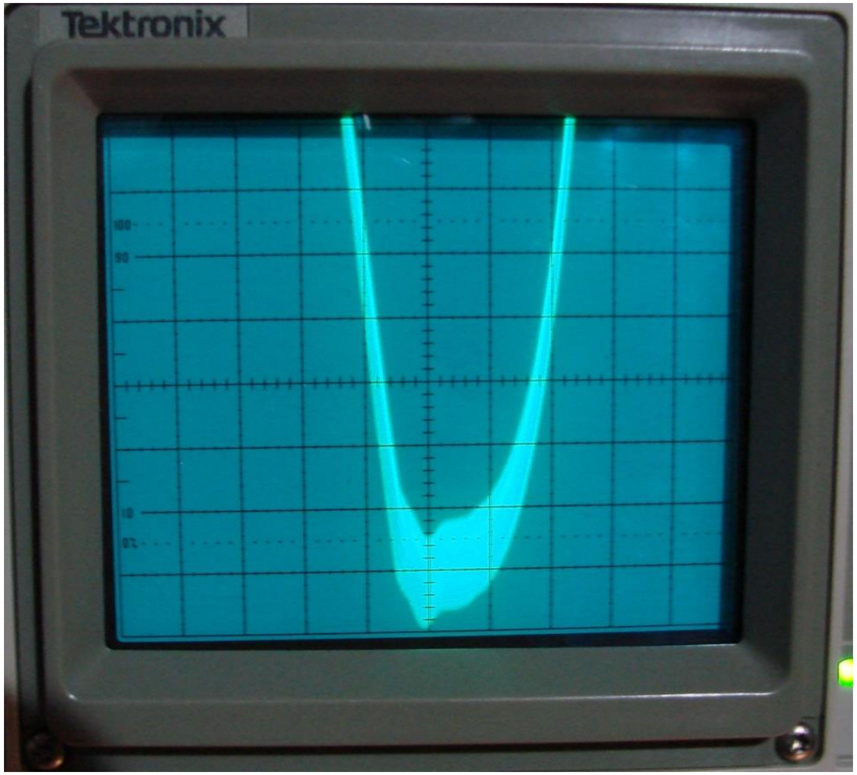
Note that the filament is connected directly to the AC line (Y-Y)

AC Test Signal

Test Signal from Modified Circuit with 6K6

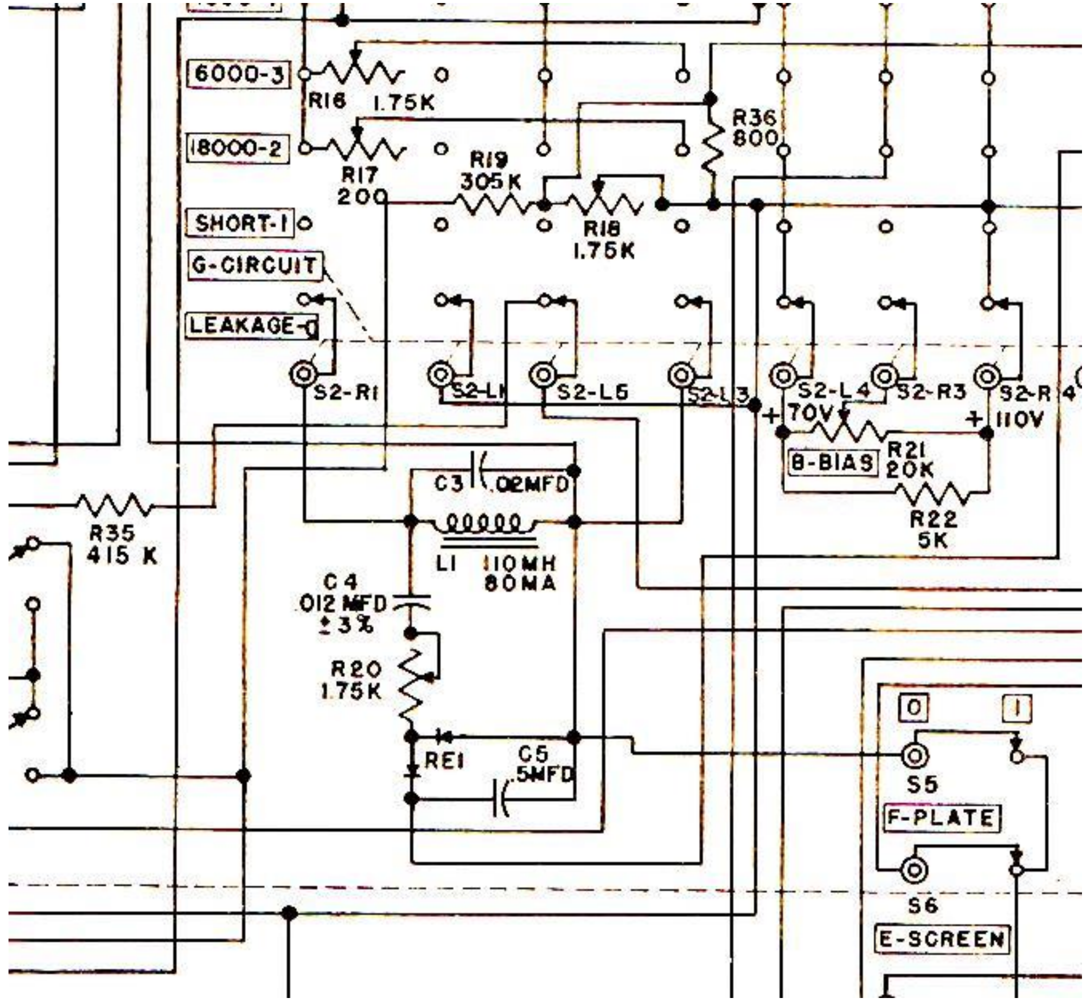


Bottom of Test Signal – Original Configuration



Test for GM

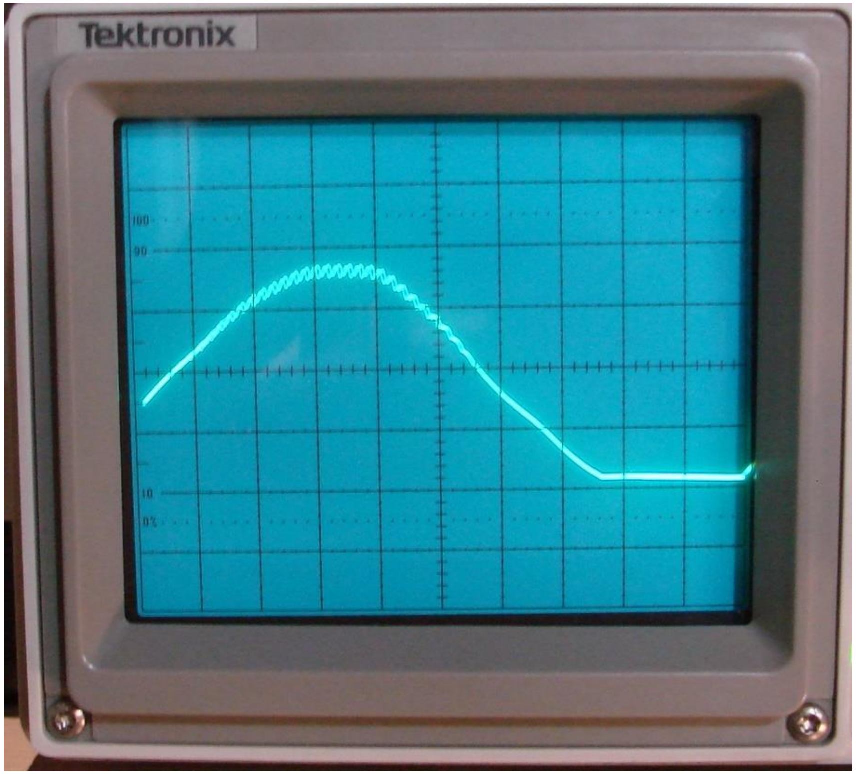
- When the test signal is impressed on the grid of the tube being tested, plate current flows through L1, 110 mH inductor.
- C3 and L1 are stated to be a resonant circuit.
- The resulting signal is rectified by diodes RE1, filtered by C5 (0.5 mF) which drives the meter.
- Different shunts provide readings on four effective scales, 1800, 6000 and 36000. The 1800 scale X10 provides the fourth (18000) scale.
- Calibration of gm scales are a mysterious process using calibration tubes.
- Gm readings cannot be relied on to square with rigorous test results. They do claim it is "proportional transconductance"!



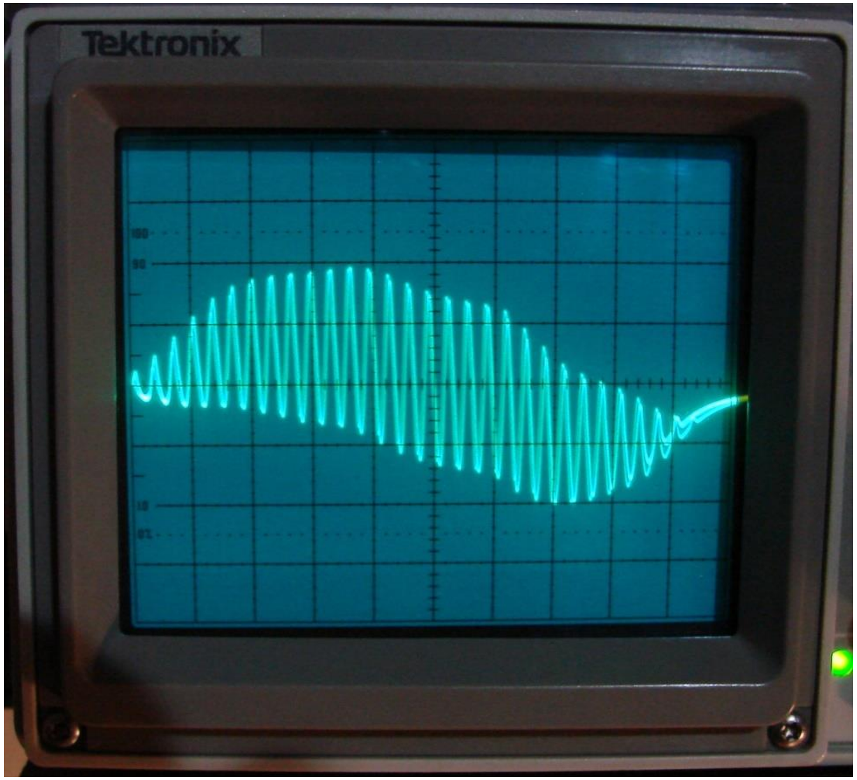
GM signal acquisition and Bias portion of the Schematic

Recovery of the Signal to Develop the Test Result

Plate to cathode, 6V6



Signal Across L1, 6V6



The test result shows as the squiggly area at the top of the waveform.

Test signal is rectified to obtain DC and applied to the meter (100 µA)

Conclusions About the Triplett 3423

- **Certainly not a true gm tester. Triplett called it "proportional transconductance".**
- **Use of bat handles different from Hickoks, seems to be a step backwards into emission testers**
- **Results are useful representation of the health of a tube.**
- **Tester is easier on small signal tubes than a TV-7. 1.2V signal vs 5V for the TV-7, 2.5V for a 6000 or 6000A.**
- **3423 calibrated and made safe about ½ the price of a TV-7B or D.**
- **Problem is the large number of TV-7s, wide familiarity and acceptance of results from a tester with numerous issues**
- **Wide variety of offerings and acceptance of the Hickok line**

Triplett's Next Step
The 3444

- ✓ Spectacular advance in "suitcase" tube testers
- ✓ Established a class of its own
- ✓ Includes a 5 kHz signal source and calibrated meter amplifier for a valid gm test.
- ✓ Applies DC voltages to tubes – not regulated
- ✓ Can be upgraded to achieve lab grade status.

The Quest for the Ideal Tube Tester

The Triplett 3444A

Successor to the 3444

- **One of the most capable testers ever made.**
- **Can deliver 150 mA at 250V (unreg.)**
- **Can test almost any small tube**
- **Actual gm test**
- **All solid state**
- **Rare and $$$**

Wrap-up

- **Hope you enjoyed the discussion**
- **Questions welcome**
- **Thanks for your attention**
- **For a full sized copy of the slides in color**

  PKHartHAVE@gmail.com. Use "RA2019" in the subject line.

Fun at Kutztown