Vacuum Tube Testing

Vacuum Tubes, Reviewing the Most Popular Hickok Testers

Paul K. Hart

SARS Winter Swap Meet
Jim Miller Park
February 18, 2017

Presentation Organization

- **Brief history of vacuum tubes – the RMA/EIA**
- **The value of date coding**
- **Methods of evaluating vacuum tubes**
- **The need to test tubes quickly and efficiently**
- **Hickok's "genius circuit" - its effect to the present**
- **Most currently popular families of Hickok testers and their characteristics**

Tube Testers and Classic Electronic Test Gear

by

Alan Douglas

- **An amazing review of tube testers, lots of Hickok information**
- **Information about testing tubes**
- **Invaluable source of information**
- **Reprints are easily available at reasonable prices**

Tube Lore
Ludwell Sibley

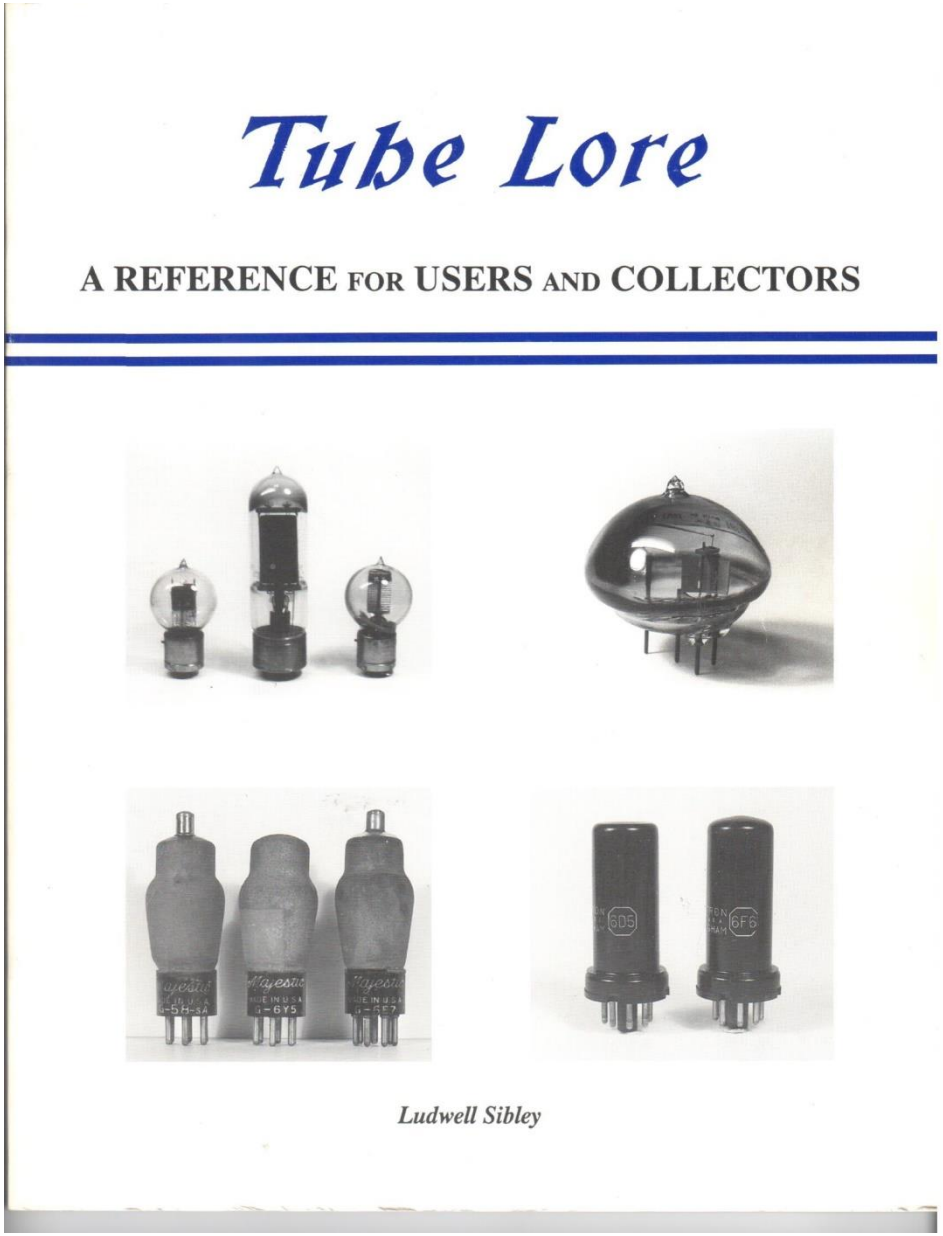
- **Published in 1996**

Three Addenda have been released

- **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.**



Standardization in Tube Designations and Performance Parameters

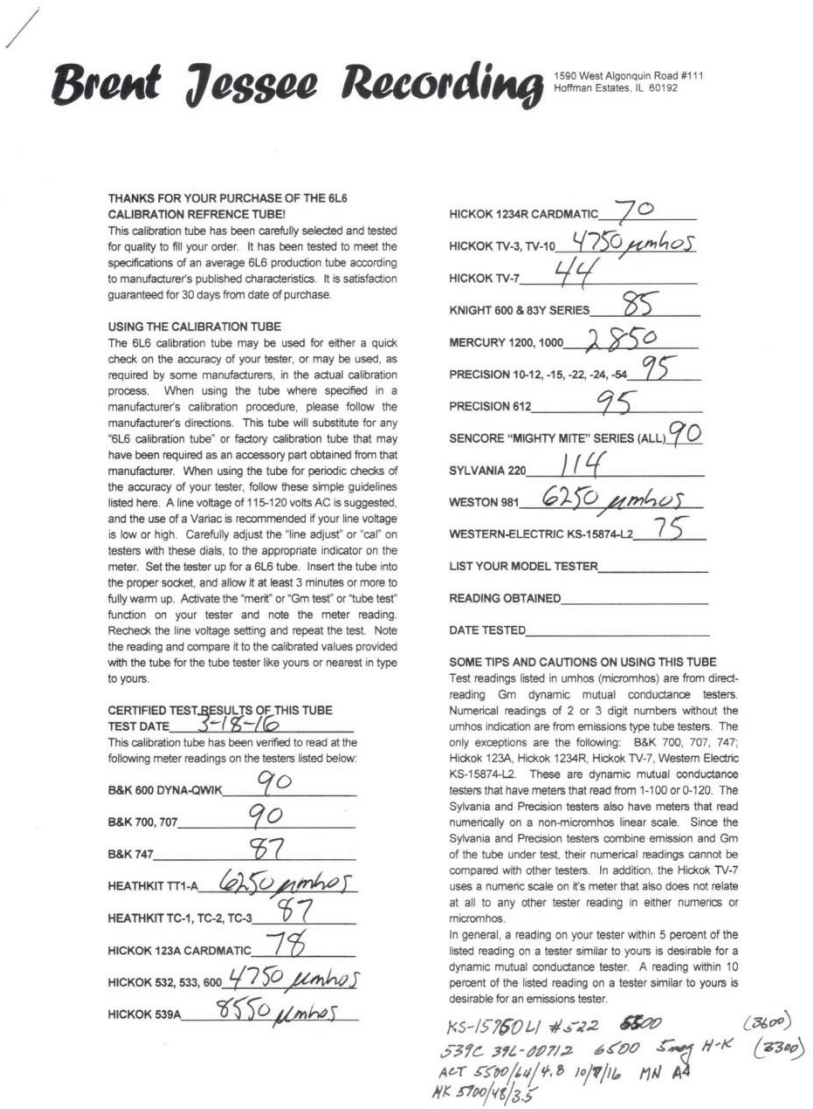
- **The period before RMA-controlled registration in 1934 is what Sibley terms “prehistory”.**
- **The industry agreed to form the RMA to develop standards to ensure that equipment of different manufacturers was compatible and interchangeable.**
- **Members agreed to common designation and performance of vacuum tubes and other devices**

Investigation

- **Disagreement about tube test results**
- **Research the literature and "prior art"**
  - **Engineering teaching texts**
  - **Industry practices, IRE 1950, General Radio, RCA instructions and elaborate testers**
- **Definition of transconductance**
  - **Change in plate current due to a change in grid voltage**
- **Build a "no excuses" tester to verify performance as the manufacturers did**
- **Use that information as a basis for evaluation of other test methods**

Calibration Tube Results on Different Testers

- From Brent Jesse Recording in IL
- Illustrates the uncertainty and difficulty of figuring out what results to accept
- Known "bogey" for a 6L6 is 6000 µmhos, 72 mA plate current 250/250/-14. Known internal factory gm limits were 5400-6600
- This tube would qualify as an in-specification tube at time of manufacture



Brent Jessee Recording
1590 West Algonquin Road #111
Hoffman Estates, IL 60192

THANKS FOR YOUR PURCHASE OF THE 6L6 CALIBRATION REFRENCE TUBE!
This calibration tube has been carefully selected and tested for quality to fill your order. It has been tested to meet the specifications of an average 6L6 production tube according to manufacturer's published characteristics. It is satisfaction guaranteed for 30 days from date of purchase.

USING THE CALIBRATION TUBE
The 6L6 calibration tube may be used for either a quick check on the accuracy of your tester, or may be used, as required by some manufacturers, in the actual calibration process. When using the tube where specified in a manufacturer's calibration procedure, please follow the manufacturer's directions. This tube will substitute for any "6L6 calibration tube" or factory calibration tube that may have been required as an accessory part obtained from that manufacturer. When using the tube for periodic checks of the accuracy of your tester, follow these simple guidelines listed here. A line voltage of 115-120 volts AC is suggested, and the use of a Variac is recommended if your line voltage is low or high. Carefully adjust the "line adjust" or "cal" on testers with these dials, to the appropriate indicator on the meter. Set the tester up for a 6L6 tube. Insert the tube into the proper socket, and allow it at least 3 minutes or more to fully warm up. Activate the "merit" or "Gm test" or "tube test" function on your tester and note the meter reading. Recheck the line voltage setting and repeat the test. Note the reading and compare it to the calibrated values provided with the tube for the tube tester like yours or nearest in type to yours.

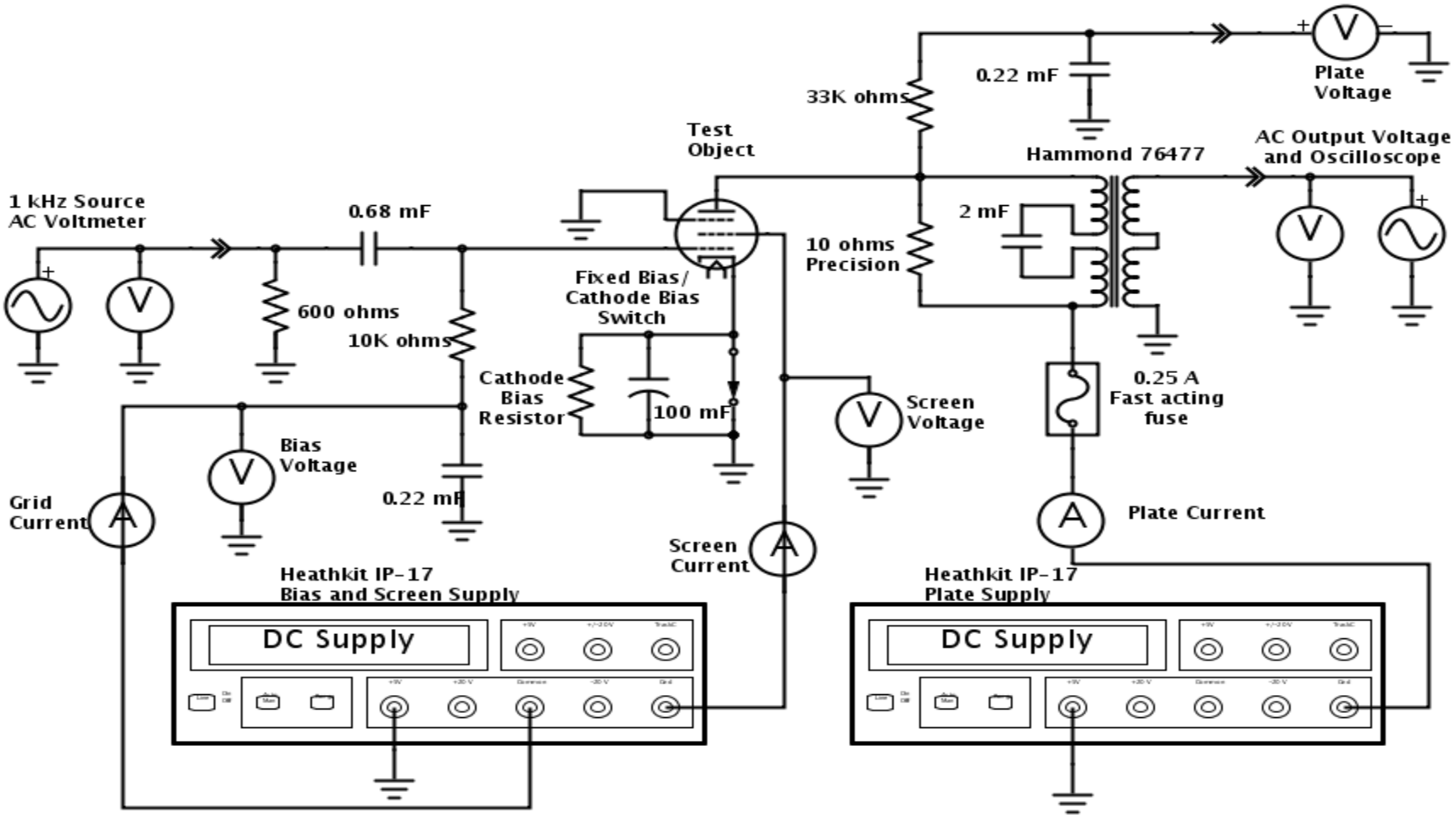
CERTIFIED TEST RESULTS OF THIS TUBE
TEST DATE 3-18-16
This calibration tube has been verified to read at the following meter readings on the testers listed below:

B&K 600 DYNA-QWIK 90
B&K 700, 707 90
B&K 747 87
HEATHKIT TT1-A 6250 µmhos
HEATHKIT TC-1, TC-2, TC-3 87
HICKOK 123A CARDMATIC 78
HICKOK 532, 533, 600 4750 µmhos
HICKOK 539A 8550 µmhos
HICKOK 1234R CARDMATIC 70
HICKOK TV-3, TV-10 4750 µmhos
HICKOK TV-7 44
KNIGHT 600 & 83Y SERIES 85
MERCURY 1200, 1000 2850
PRECISION 10-12, -15, -22, -24, -54 95
PRECISION 612 95
SENCORE "MIGHTY MITE" SERIES (ALL) 90
SYLVANIA 220 114
WESTON 981 6250 µmhos
WESTERN-ELECTRIC KS-15874-L2 75
LIST YOUR MODEL TESTER
READING OBTAINED
DATE TESTED

SOME TIPS AND CAUTIONS ON USING THIS TUBE
Test readings listed in umhos (micromhos) are from direct-reading Gm dynamic mutual conductance testers. Numerical readings of 2 or 3 digit numbers without the umhos indication are from emissions type tube testers. The only exceptions are the following: B&K 700, 707, 747; Hickok 123A, Hickok 1234R, Hickok TV-7, Western Electric KS-15874-L2. These are dynamic mutual conductance testers that have meters that read from 1-100 or 0-120. The Sylvania and Precision testers also have meters that read numerically on a non-micromhos linear scale. Since the Sylvania and Precision testers combine emission and Gm of the tube under test, their numerical readings cannot be compared with other testers. In addition, the Hickok TV-7 uses a numeric scale on it's meter that also does not relate at all to any other tester reading in either numerics or micromhos.
In general, a reading on your tester within 5 percent of the listed reading on a tester similar to yours is desirable for a dynamic mutual conductance tester. A reading within 10 percent of the listed reading on a tester similar to yours is desirable for an emissions tester.

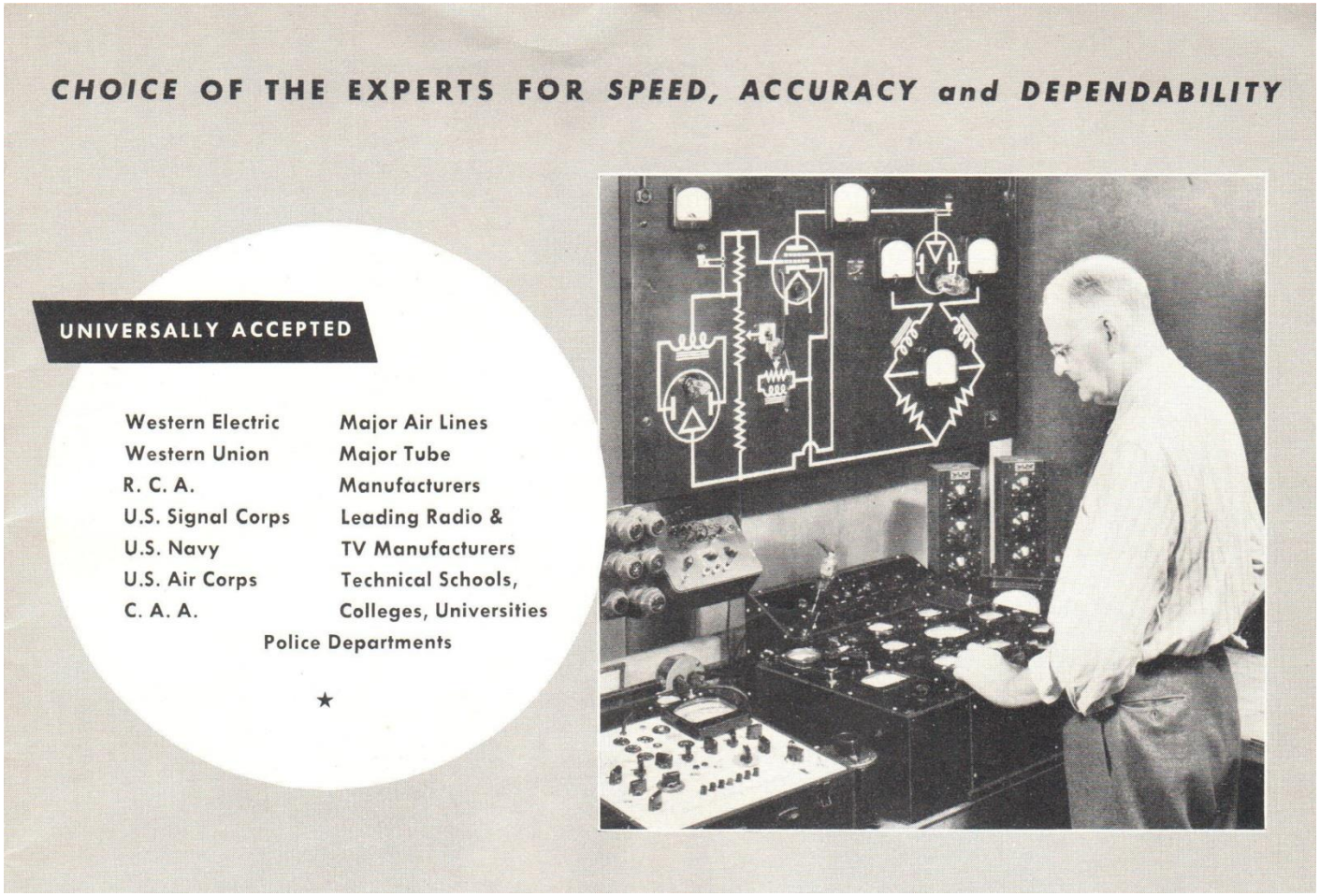
KS-15760 L1 #522 6500 (3600)
539C 396-0071-2 6500 Sm H-K (3300)
ACT 5300/44/4.8 10/9/16 MN AA
HK 5700/48/3.5

Schematic of Lab Tester



Jagundo Tester
RadioActivity 2014

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 discussion.

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

Filament arrangement not shown, but significant.

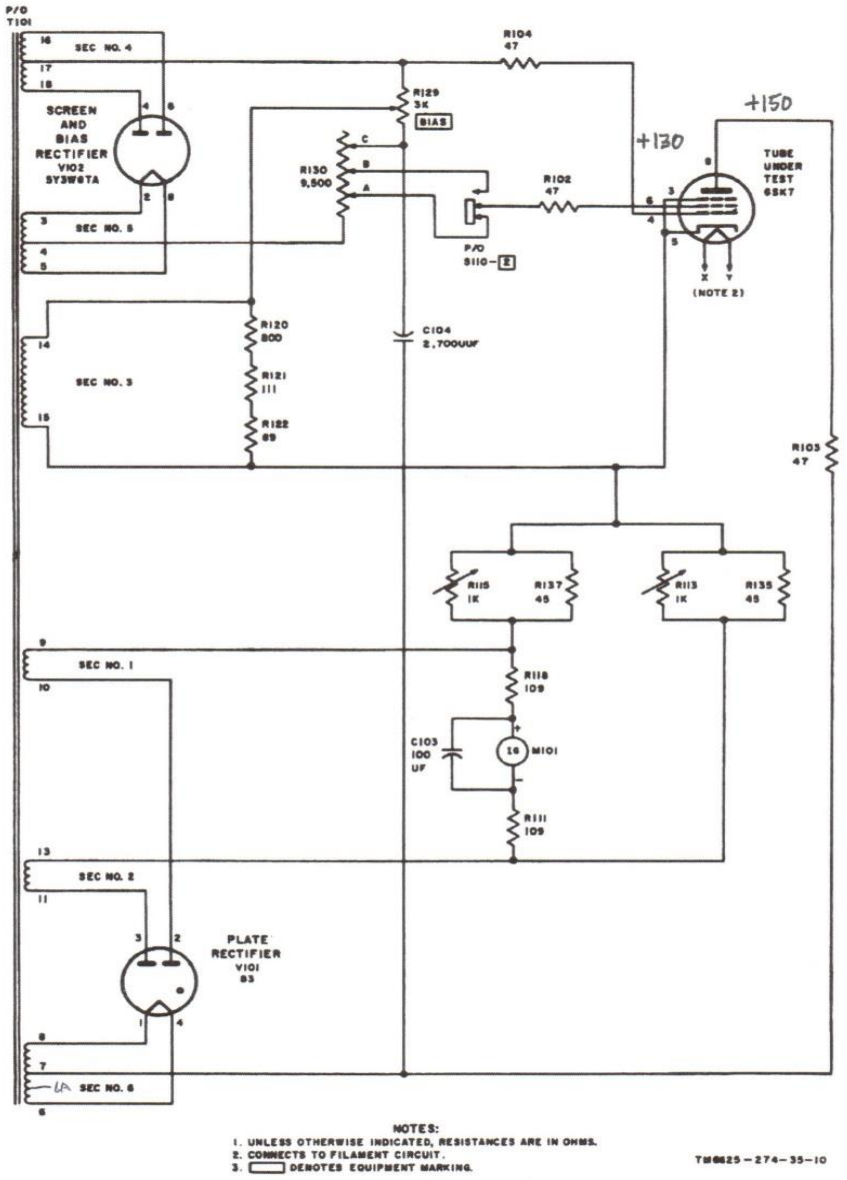


Figure 11. Simplified mutual conductance test circuit, TV-7D/U.

16

Common Characteristics of all Hickok Testers

- **Chopped AC was used for testing - 150V plate**
- **Screen voltage – 135V was shared with bias – all chopped AC**
- **Signal voltage is full cycle**
- **Transconductance inferred by reading difference between two legs of the bridge**
- **Special tubes (6L6) required for calibration**
- **No electrolytic capacitors were needed**

Perspectives on Calibration and the issue of Calibration Tubes

- **Hickok has left many clues as to calibration techniques using calibration tubes.**
  - **Adjustments provided in later TV-7 series**
  - **Calibration instructions for 6000 and using shunt pot mismatch for transconductance calibration**
  - **Schematic notations in other testers**
- **Use of AC surrogate technique**
  - **Recommended for many testers, very coarse**
  - **Contrary conclusion: Calibration tubes are required**

The Ubiquitous Calibration Tube The Metal 6L6

- ✓ **A huge number were made – lots to choose from**
- ✓ **Durable**
- ✓ **Inexpensive**
- ✓ **Many sources offer to sell you a calibration 6L6**
- ✓ **Each one has its own construct of valid calibration**

Calibration Tube Dilemma

- **Each type of tester is set up differently**
- **Hickok closely guarded their standard test tubes**
  - **Web information, Daniel Schoo**
- **Even if you could find one of the originals today, you couldn't trust it**
- **New calibration tubes must be created**
- **Many assumptions are required, increasing complexity and controversy**
- **A 6L6 is not all you need - qualifications**

Selection of a Calibration Tube

- **6L6s can exhibit different tendencies in leaking filament voltage into the signal**
- **To separate the ones that do from those that don’t, you need to switch the filament connections**
- **Other considerations, test results from the jagundo tester**

TV-7D/U Switch Group

Filament Connections “H-S Format”

Applies to TV-7, 539B, C, 6000 series

F-R format applies to TV-3, TV-10, 539A, 600, 800, Western Electric.
Look up 6L6 on the roll chart of your tester to be sure.

Left Switch	Pin		Right Switch	Pin
A	open		P	open
B	1		R	1
C	2		S	2
D	3		T	3
E	4		U	4
F	5		V	5
G	6		W	6
H	7		X	7
J	8		Y	8
K	9		Z	open

Implications of Hickok Design

- **The filament leakage issue applies to all tubes**
  - **Do you have to check each tube twice and average?**
  - **Affects all tubes being tested**
- **The tube being tested drives the meter directly**
  - **Many tubes don't have the power to drive the meter without overdriving the tube**
- **Unique circuit and test conditions make it impossible to relate gm readings to actual transconductance**

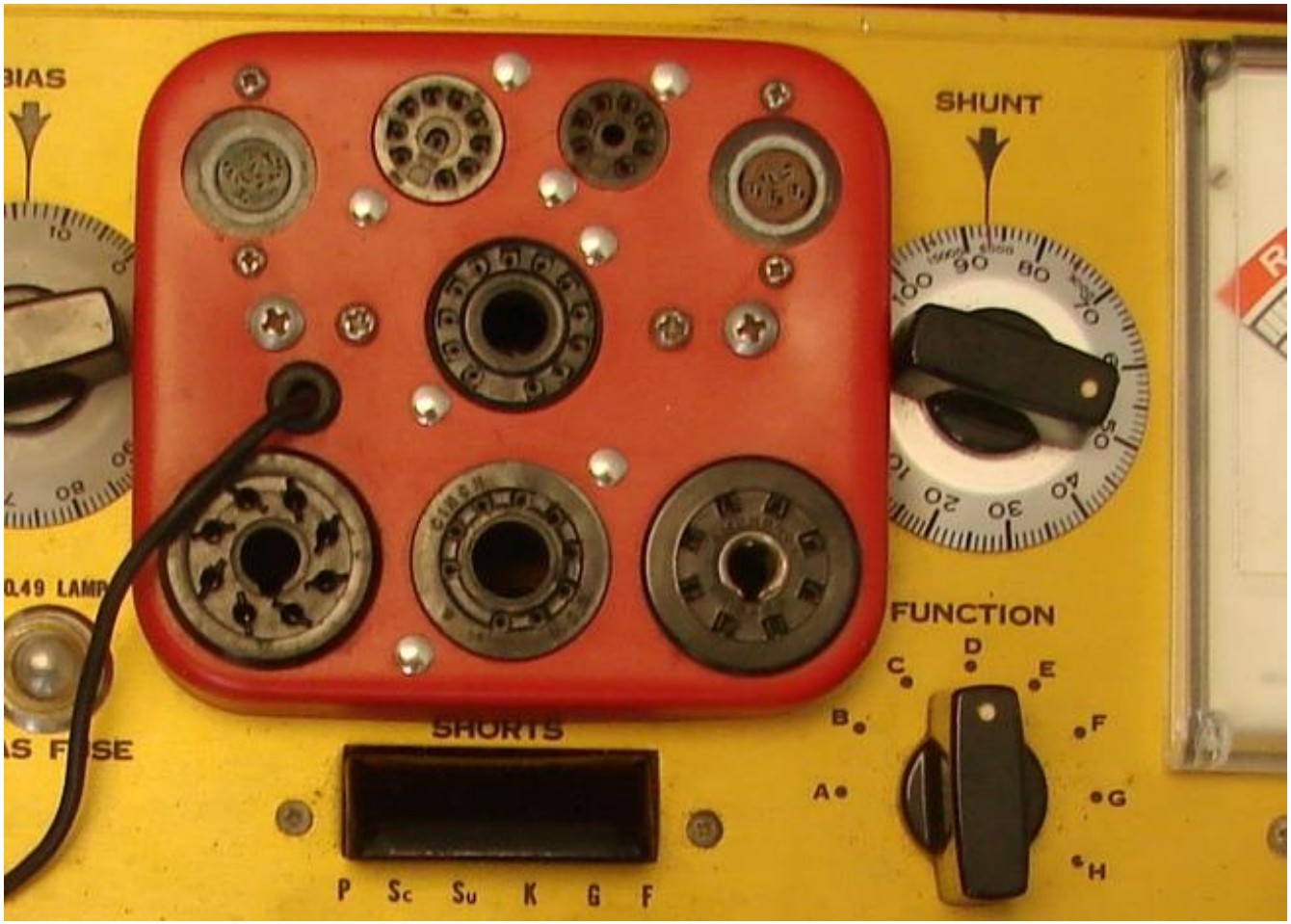
Four Major Hickok Tester Families

- **Lower level service testers**
  - **600, 800, 6000, 6000A**
- **Military Versions**
  - **I-177, TV-3, TV-7, TV-10**
- **“Laboratory” Testers**
  - **539, 539A, 539B, 539C**
- **Special versions for Western Electric**
  - **KS-15559-15560, KS-15750 (Hickok RD-1575)**

6000A

6000A
Dropped legacy sockets, 14 position switches

6000A Socket Island



Sockets: 2 Nuvistor, 7 and 9 pin
Octal and loktal, Compactron and Novar

Hickok 6000, 6000A

- **All tubes tested with 2.5VAC signal voltage**
- **Mainly used for good/bad readings based on shunt pot setting**
- **Reading of gm using alignment of scale ranges marked on shunt pot**
- **Readings sensitive to small variations in setting the shunt pot**
- **Unique shorts test - very sensitive, maybe too sensitive**

Hickok 6000, 6000A Cont'd

- **Panel space for sockets restricted**
- **Socket "islands" used for earlier and later sockets**
- **6000 had earlier sockets and more limited switching**
- **6000A dropped legacy sockets and added novar and compactron sockets with increased switching.**

6000

Legacy sockets, 7 and 9 pin, octal and loktal
12 position switches

6000 Socket Island

Hickok Military Testers

- **I-177s are often seen, OK for early tubes, but not a modern tester**
- **TV-7 came on the scene in 1952. Was widely produced, compact, rugged and easy to use.**
  - **TV-7/U Phenolic switches, fixed elements**
  - **TV-7A/U Ceramic switches, adjustable elements**
  - **TV-7B/U Ceramic switches, physical changes**
  - **TV-7D/U Ceramics, more changes, added F scale to Function switch**

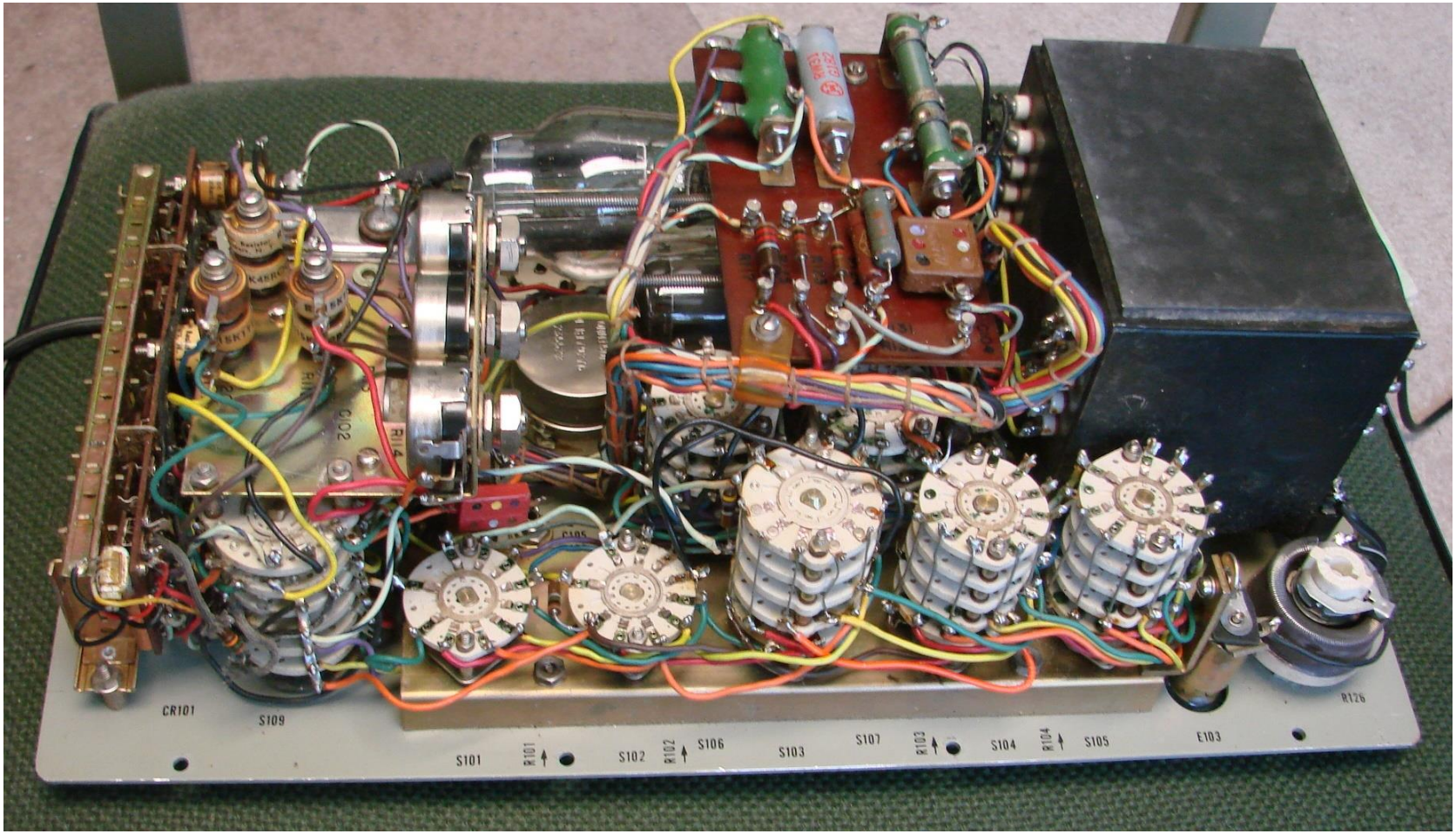
TV-7/U First Production Version

Take note of the skirted dials on the Bias and Shunt controls.
Later variants had number settings engraved in the panel.

TV-7 Characteristics

- **Extremely rugged, well built (no rivets), small size, easy to operate**
- **Uses 5V signal test voltage on B, C, scales, 1V on D and 1/2V on E scale**
- **Shunt pot used only in testing rectifiers**
- **Gm readings are taken from a 0-120 scale and compared to no-go values on setup chart**
- **Many smaller signal tubes are heavily over driven by testing**

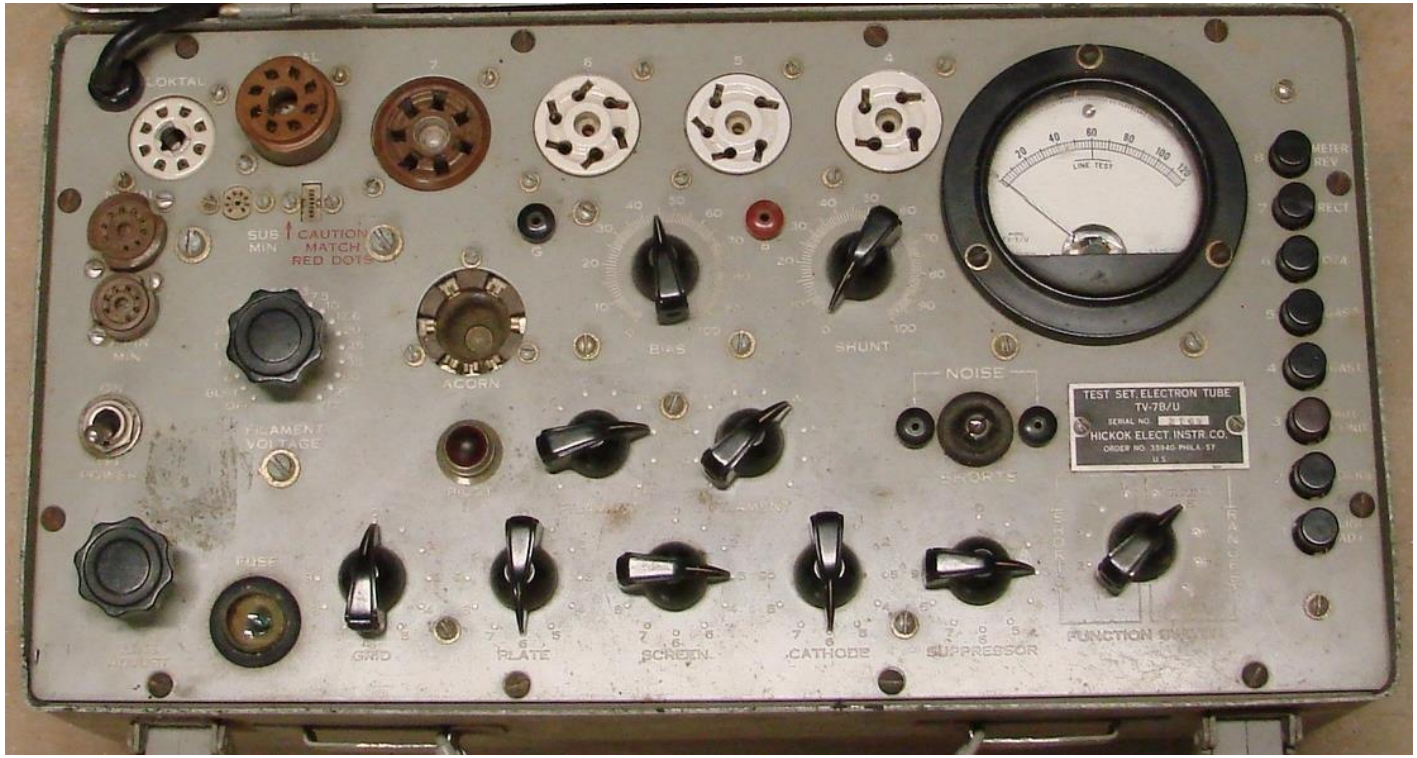
TV-7A/U Underside



TV-7 Characteristics, Cont'd.

- **Wide recognition of meaning of TV-7 test numbers**
- **Huge quantities made, junkers for parts; make maintenance in the long term possible**
- **Misrepresentation made easy by simple transfer of ID plates**
- **Sockets for acorn, subminiature tubes**
- **Cannot test novar or Compactron tubes without adapters**

TV-7B/U



Typical B in good condition as found. B variant made by Forway and Hickok. This one by Hickok, 1957 contract.

539 Series of “Laboratory” Testers

Evolution from the 532, 533, 534, 536, 538 series

- **Started with the 539 in 1950, no bias meter**
- **Quickly superseded by the 539A with added bias meter and other changes**
- **No line test, now had line set meter**
- **Separate transformers for gm and filament power**
- **539 and 539A were F-R series testers**
- **Unique gm meter makes them difficult to maintain**
- **Less complex than the later variants**
- **Served as the basis for a new line of testers for sale to Western Electric for use in the Bell System**

539, 539A

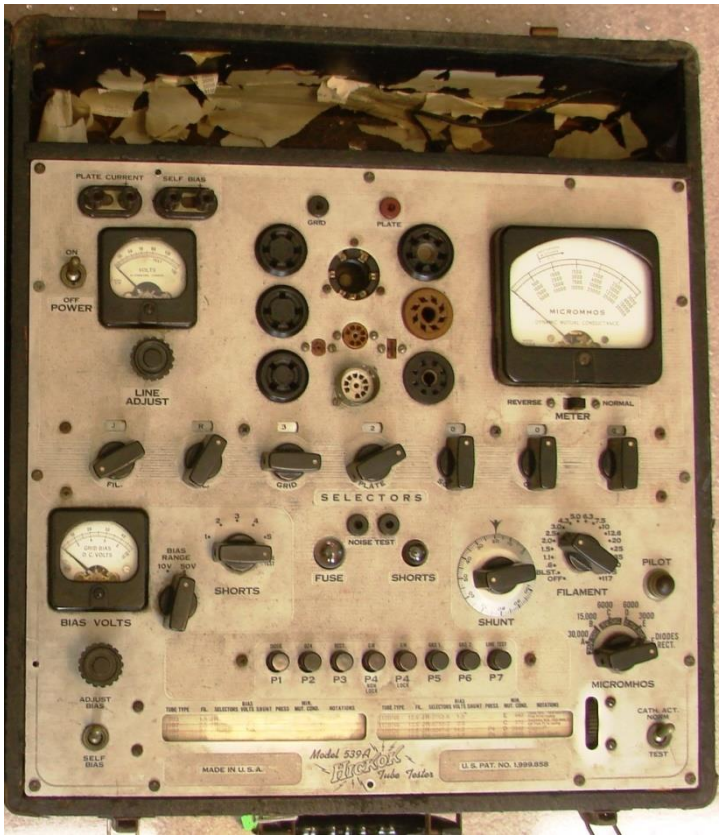
539

Old type bias dial, no bias meter

15,000 gm scale highest

539A

Added bias meter, 30,000 gm scale



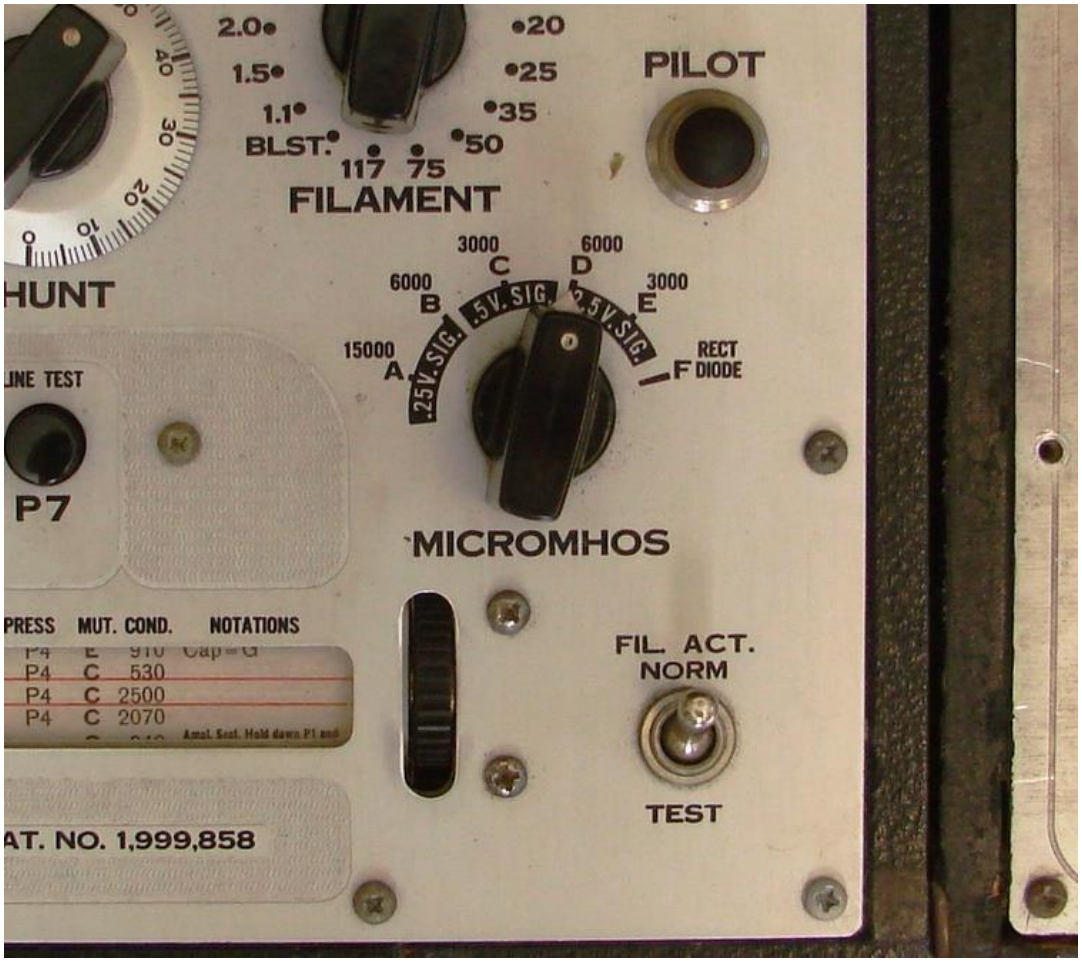
Advances in the 539 Series

- **More sensitive meters for testing low energy tubes**
- **New functionalities in the micromho selection switch**
  - **Selection of lower levels of signal voltage to reduce overdriving of tubes being tested**
  - **Concurrent changing of bridge resistance values for greater flexibility**
- **More test options in pushbuttons**

539 Micromhos Control

Major Step Forward

- **Addition of multiple steps in signal level**
- **Coordinated with additional matching steps of gm full scale on meter by changing values in the bridge resistors**
- **12AX7 now tested at 0.5V instead of 2.5 V (6000) or 5 V (TV-7).**
- **Makes the tester more complex but much more consistent, especially with low energy tubes**



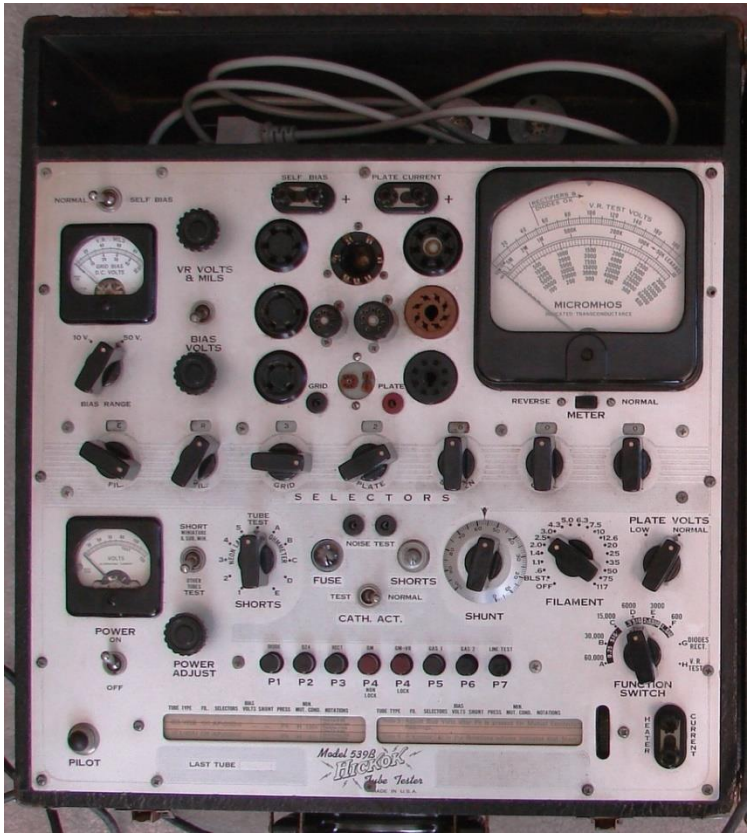
Hickok 539 B and C

539B

Most big gm meter, square bias and line meters

Meters are rare and difficult to replace

Will test acorn tubes but not novar or compactron

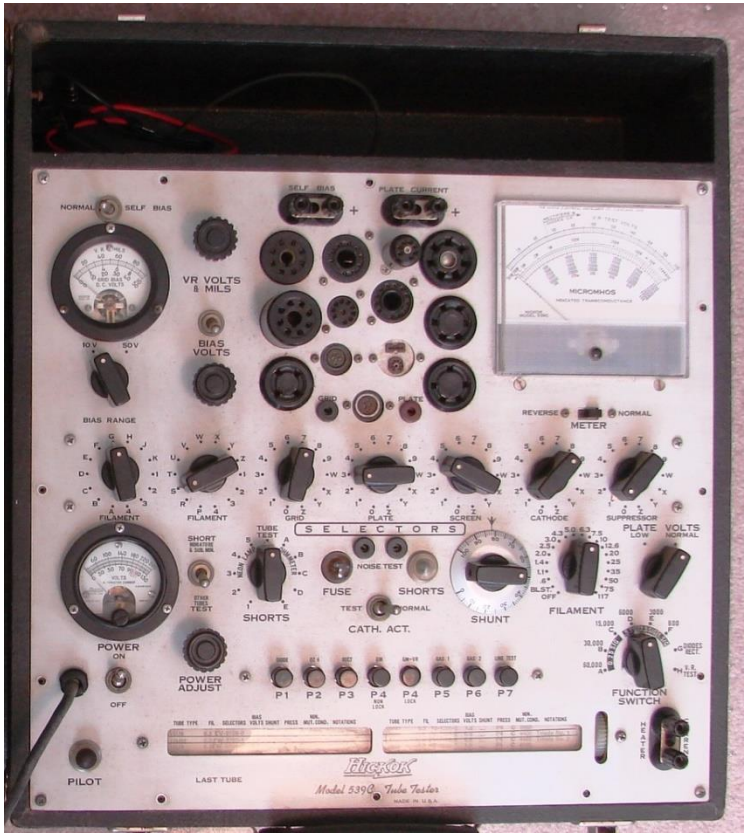


539C

Most either big and smaller gm meters as well as round bias and line meters – replacements rare

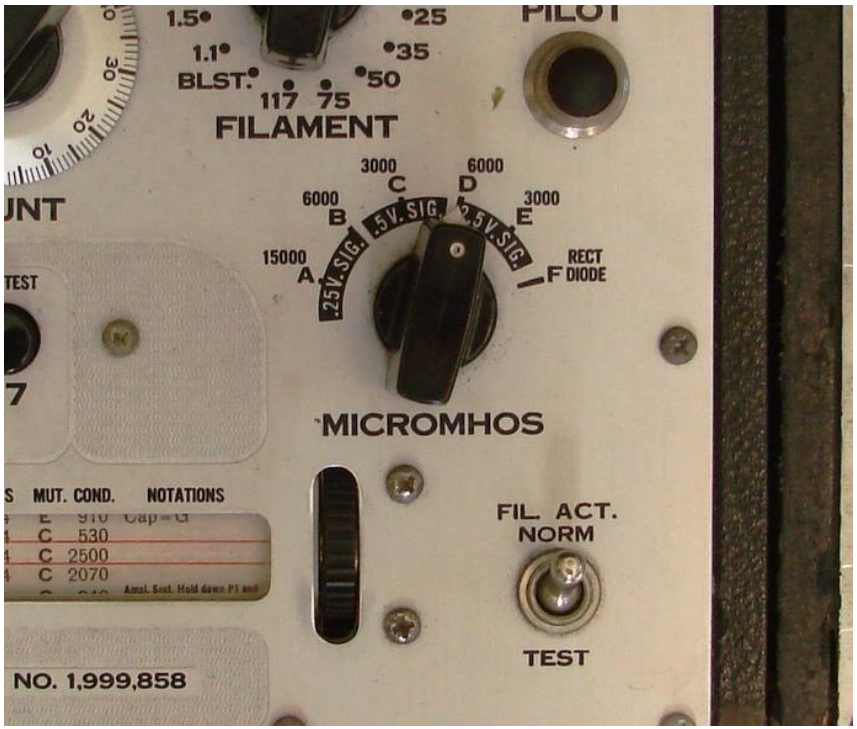
Added novar and compactron sockets and switching

Dropped acorn socket

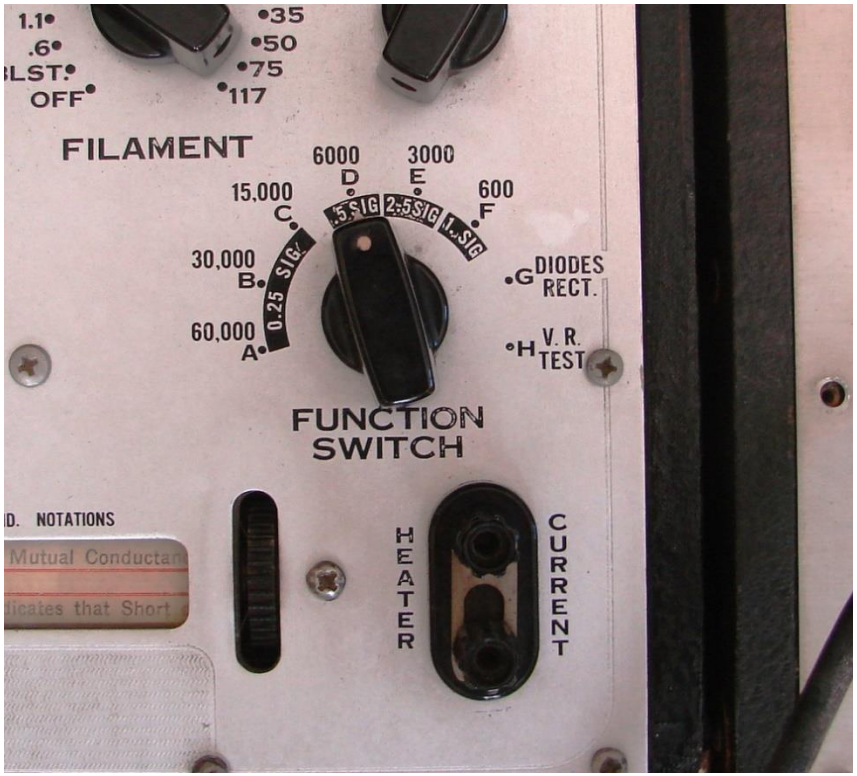


539 and 539B Function Comparison

539 Microhmos (function) control
Max. gm scale is 15,000
30,000 added in 539A



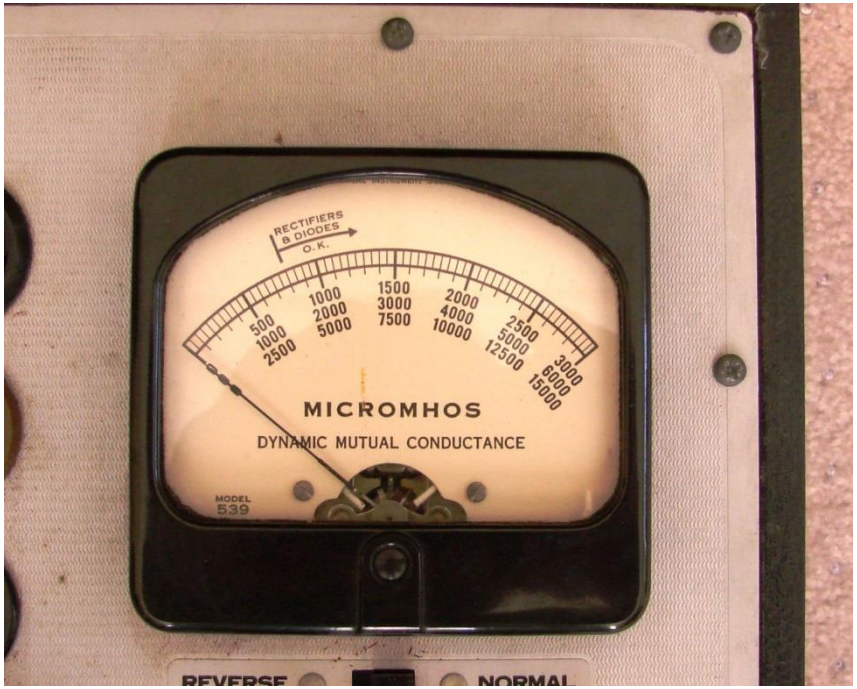
539 B and C Function are the same
Max. gm scale is 60,000; lowest is 600. Added VR Test



539 and 539B Meters

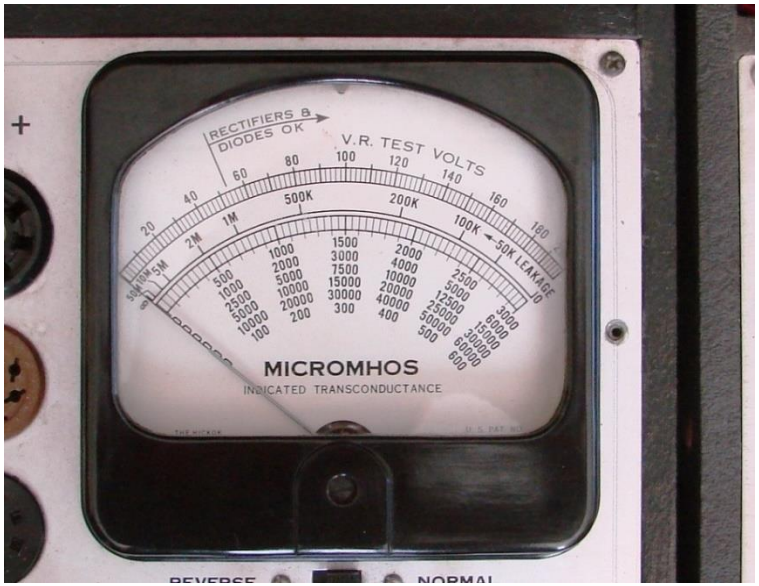
Increased Complexity and Evolution of Terminology

539, 3 scales and diodes



Dynamic Mutual Conductance

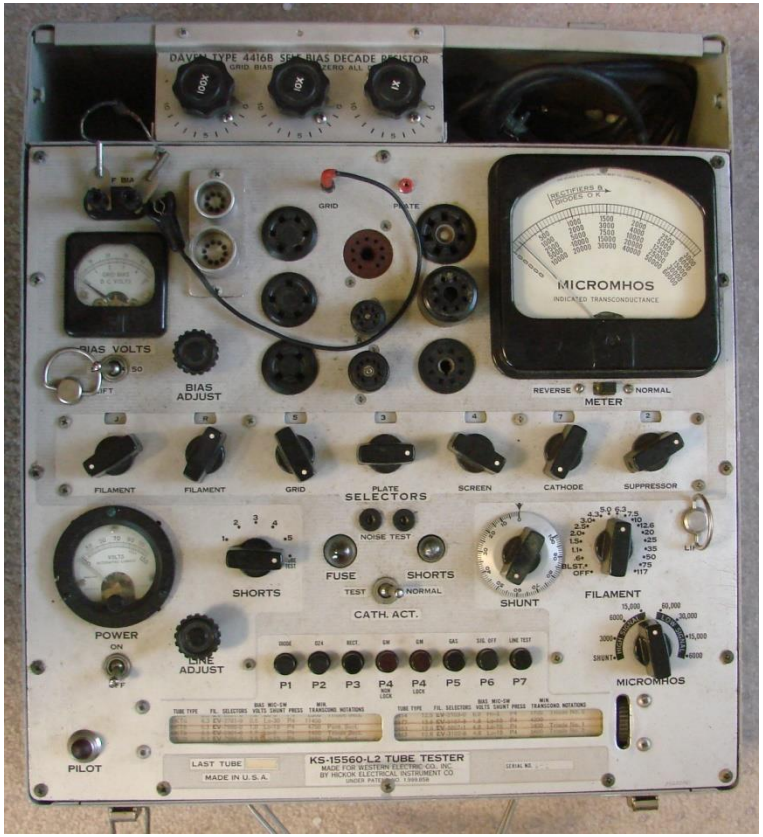
539B, 8 scales and diodes



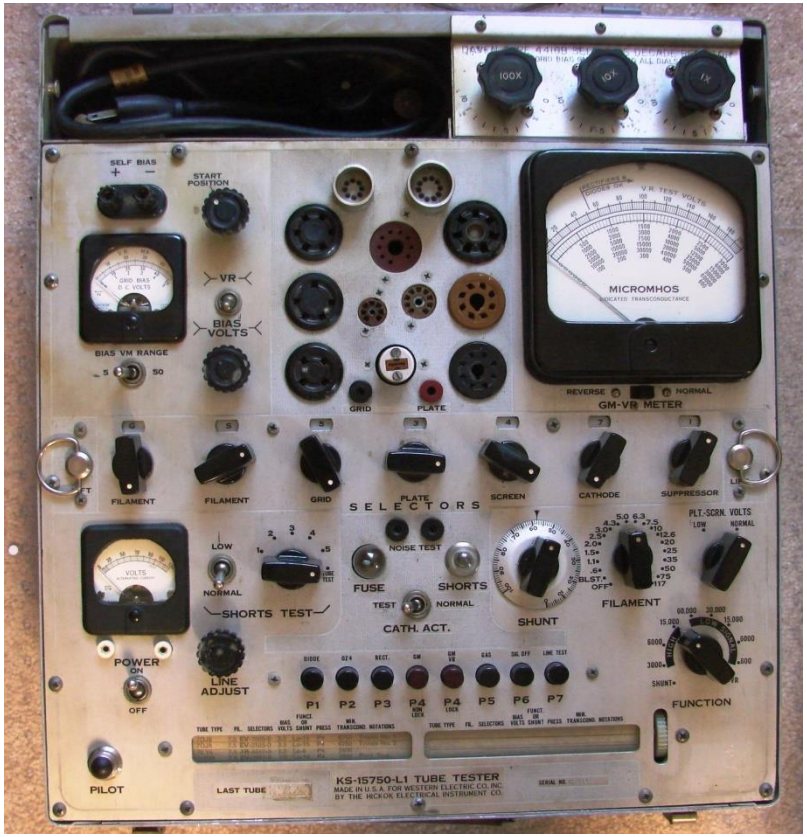
Indicated Transconductance

Hickok Testers for Western Electric

KS-15560, L1, L2
Most often seen in wooden box case
Without the Daven decade



KS-15750, L1, L2
Most often seen in metal case with Daven
3 stage resistance decade



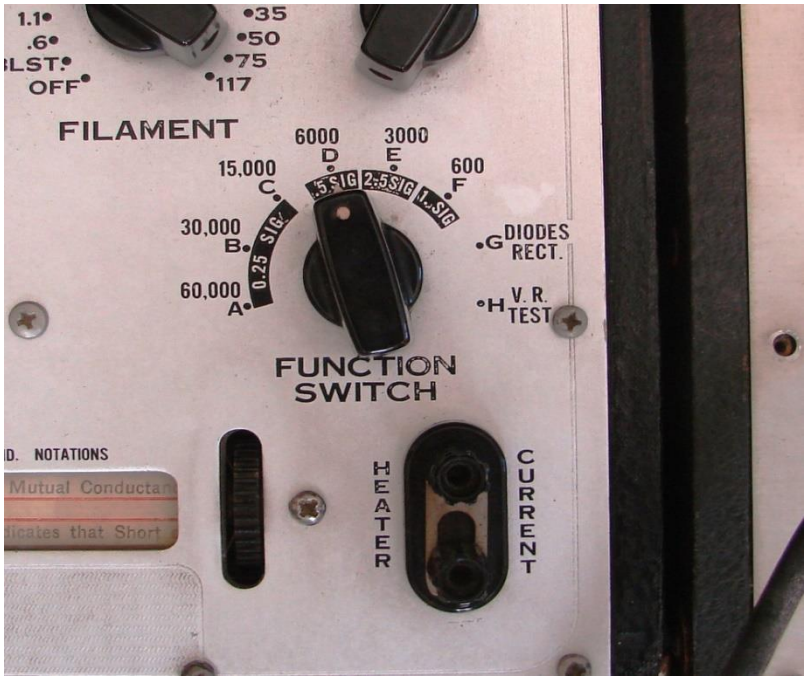
Major differences between Hickok commercial and WECo testers

539B/C Function Switch

Signal voltages were lowered

Bias still chopped AC and shared with screen

Function switch steps through different bridge values and signal voltages.



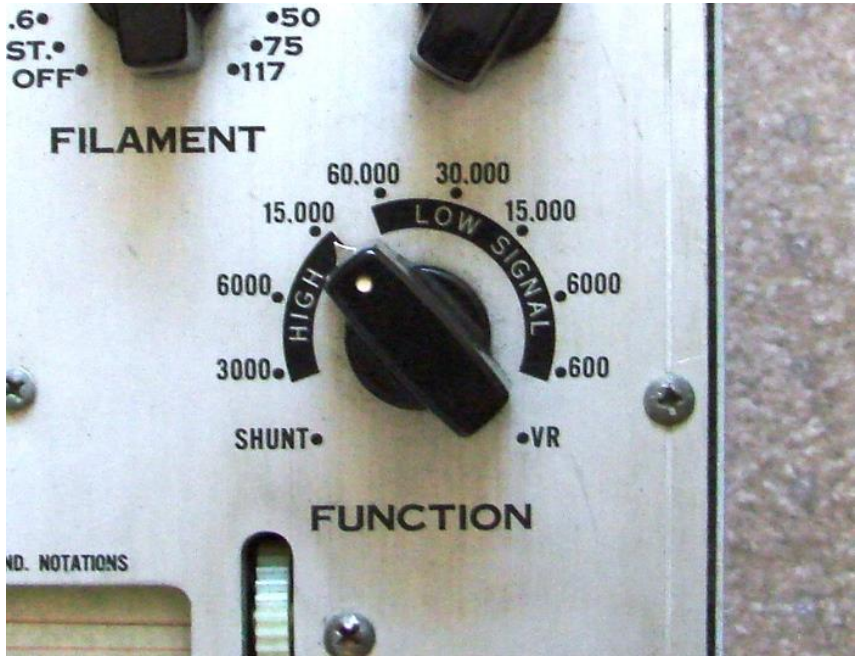
KS-15750 Function Switch

Bias was filtered DC, no sharing with screen

Different bridge values from Hickok commercial

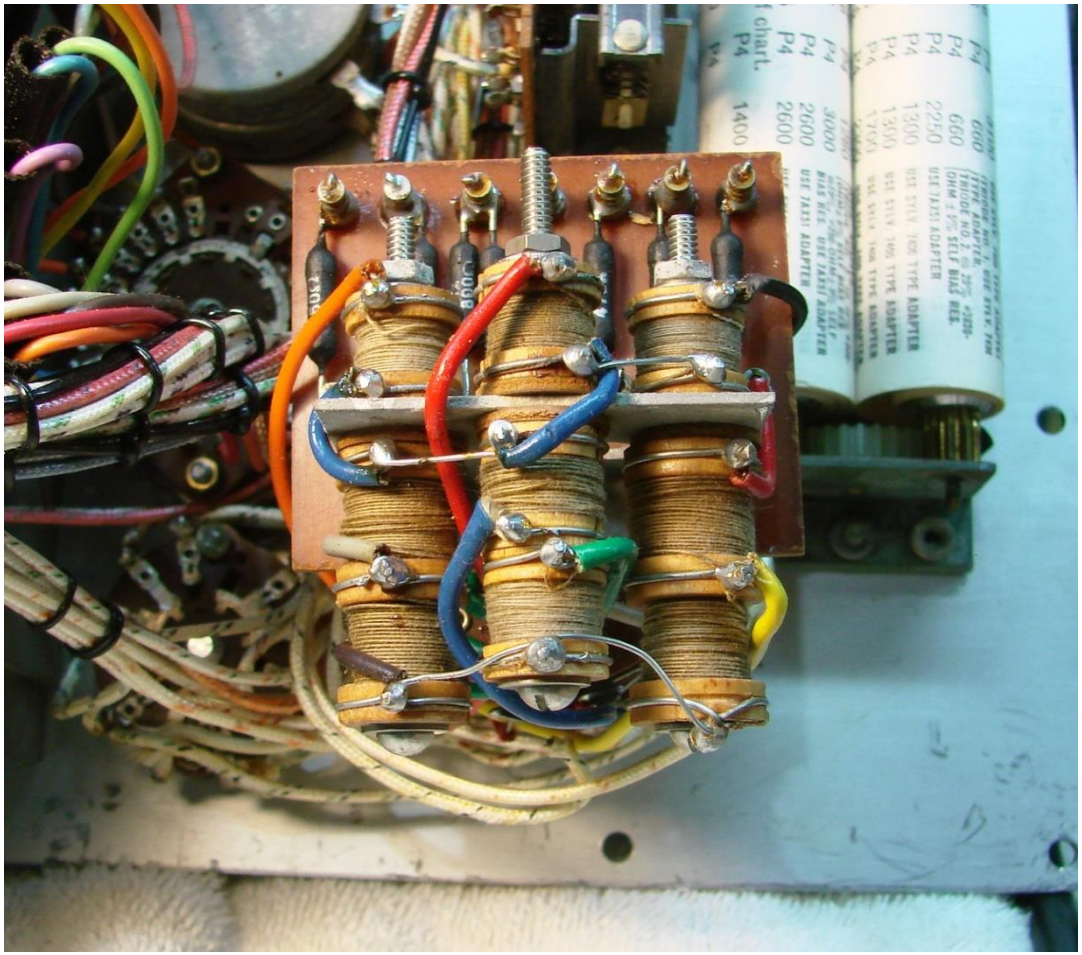
Signal voltages not stated, high is 5V!

Low is 0.25, 0.5, 1, 1, 1.



Control of critical functions of the 539, WECo and TV7 testers

- **Precise resistance of "spools", which were resistances wound on bobbins in production**
- **Photo at right is of the primary 9 spool set in a WECo KS-15750**
- **Open wound resistances that can be trimmed. Resistance values recorded in pencil on the spool.**
- **TV-7 spools were mass produced, to specific values and sealed**
  - **But the TV-7, from the A on had adjustments**
- **Basic assumption is that spools will hold their original values forever. Really?**



Western Electric Perspective

From Bell System Practices

Section 100-636-101

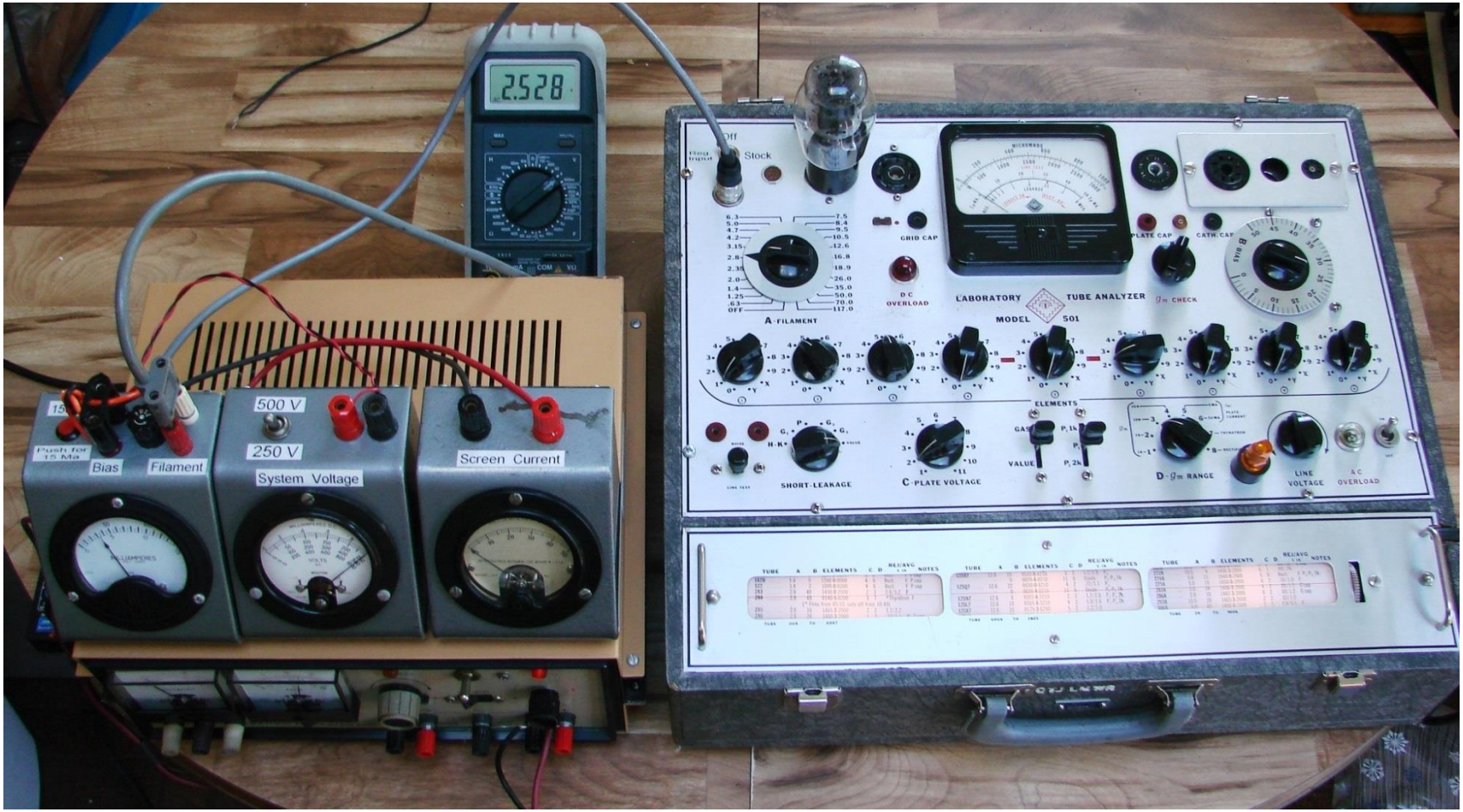
Issue 3, January 1962

AT&TCo Standard

Paragraph 2.23:

"…..The amount of deflection is proportional to the transconductance of the tube under test, but under these test conditions is not a rigorous measurement of the transconductance. For this reason it is referred to herein as 'indicated transconductance'".

The Quest for the Ideal Tube Tester



Wrap-up

- **Hope you enjoyed the discussion**
- **Testers available for testing and familiarization**
- **Thanks for your attention**
- **For a copy of the slides in color**

  PKHartHAVE@gmail.com. Use "Miller" in subject line.