Vacuum Tube Testing

Vacuum Tubes, Reviewing the Most Popular Hickok Testers

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SARS Winter Swap Meet
Jim Miller Park
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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 µhmhos, 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
Schematic of Lab Tester

- 1 kHz Source AC Voltmeter
- 0.68 mF
- 600 ohms 10K ohms
- Cathode Bias Switch
- 33K ohms
- Test Object
- Hammond 76477
- AC Output Voltage and Oscilloscope
- 0.22 mF
- 2 mF
- 0.25 A Fast acting fuse
- Screen Voltage
- Screen Current
- Heathkit IP-17 Bias and Screen Supply
- DC Supply
- Plate Voltage
- Plate Current
- DC Supply
- Heathkit IP-17 Plate Supply

Grid Current

Bias Voltage 0.22 mF

Fixed Bias/ Cathode Bias Switch

Cathode Bias Resistor 100 mF
The Hickok “Genius Circuit” and its Legacy

CHOICE OF THE EXPERTS FOR SPEED, ACCURACY and DEPENDABILITY

UNIVERSALLY ACCEPTED

Western Electric
Western Union
R. C. A.
U.S. Signal Corps
U.S. Navy
U.S. Air Corps
C. A. A.

Major Air Lines
Major Tube
Manufacturers
Leading Radio &
TV Manufacturers
Technical Schools,
Colleges, Universities
Police Departments

Is this Job Barnhart?
Simplified TV-7 Gm Test Circuit
From military manual, pg. 16

U.S Department of the Army,

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.
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.

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<th>Pin</th>
<th>Right Switch</th>
<th>Pin</th>
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<td>K</td>
<td>9</td>
<td>Z</td>
<td>open</td>
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</table>
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

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.
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

539B, 8 scales and diodes

Dynamic Mutual Conductance

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?
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.