

Vacuum Tube Testing

**Topics on Vacuum Tubes, Hickok
Testers and Researching the Past**

MAARC RadioActivity

June 25-27, 2015

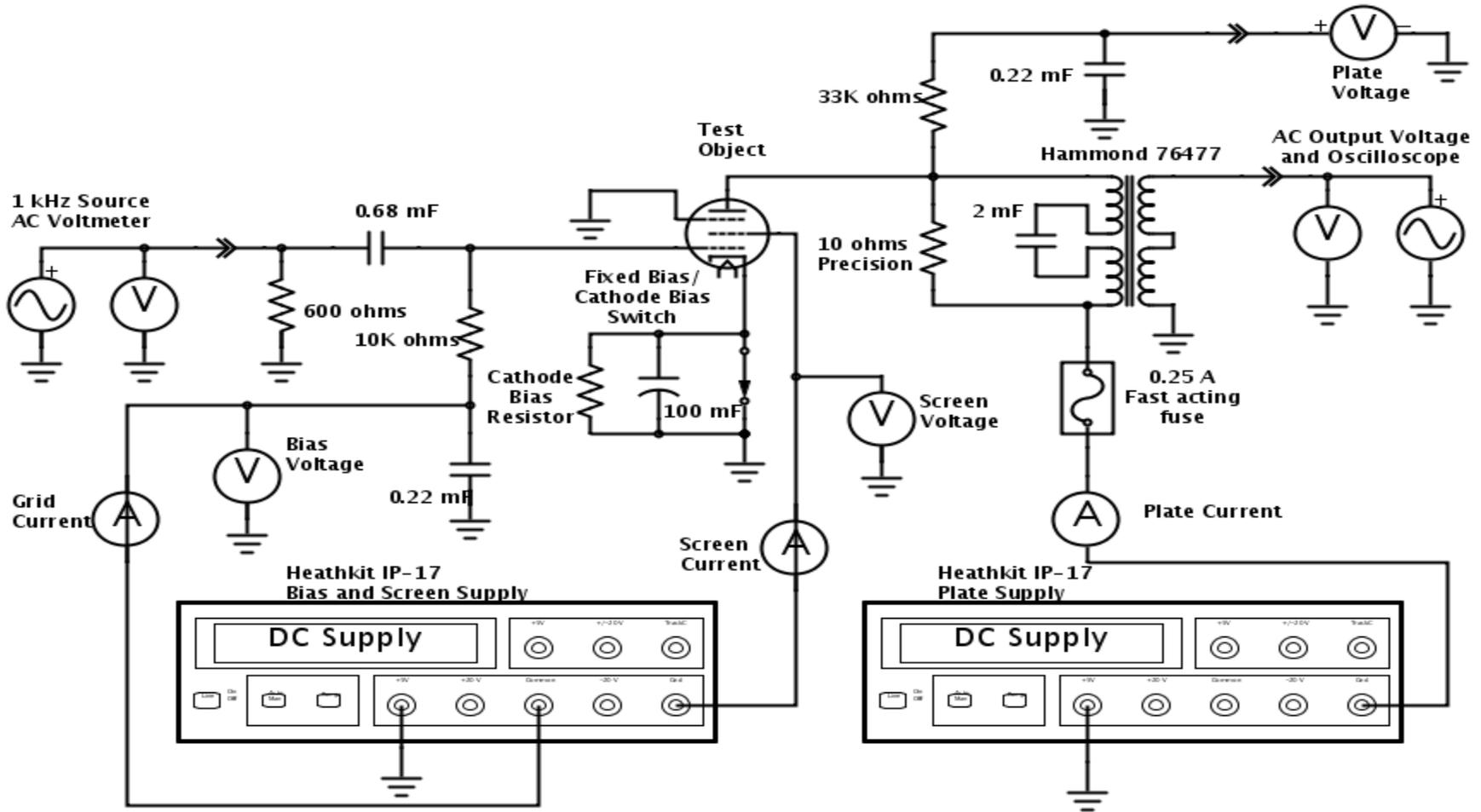
Presentation Organization

- **A quest for methods of evaluating vacuum tubes**
- **Hickok's "genius circuit" - its effect to the present**
- **Date coding – does it matter?**
 - **Sylvania/GE inquiry**
 - **A chart relating different manufacturers codes**
- **Research on tube information**
 - **RCA information releases**

The Quest

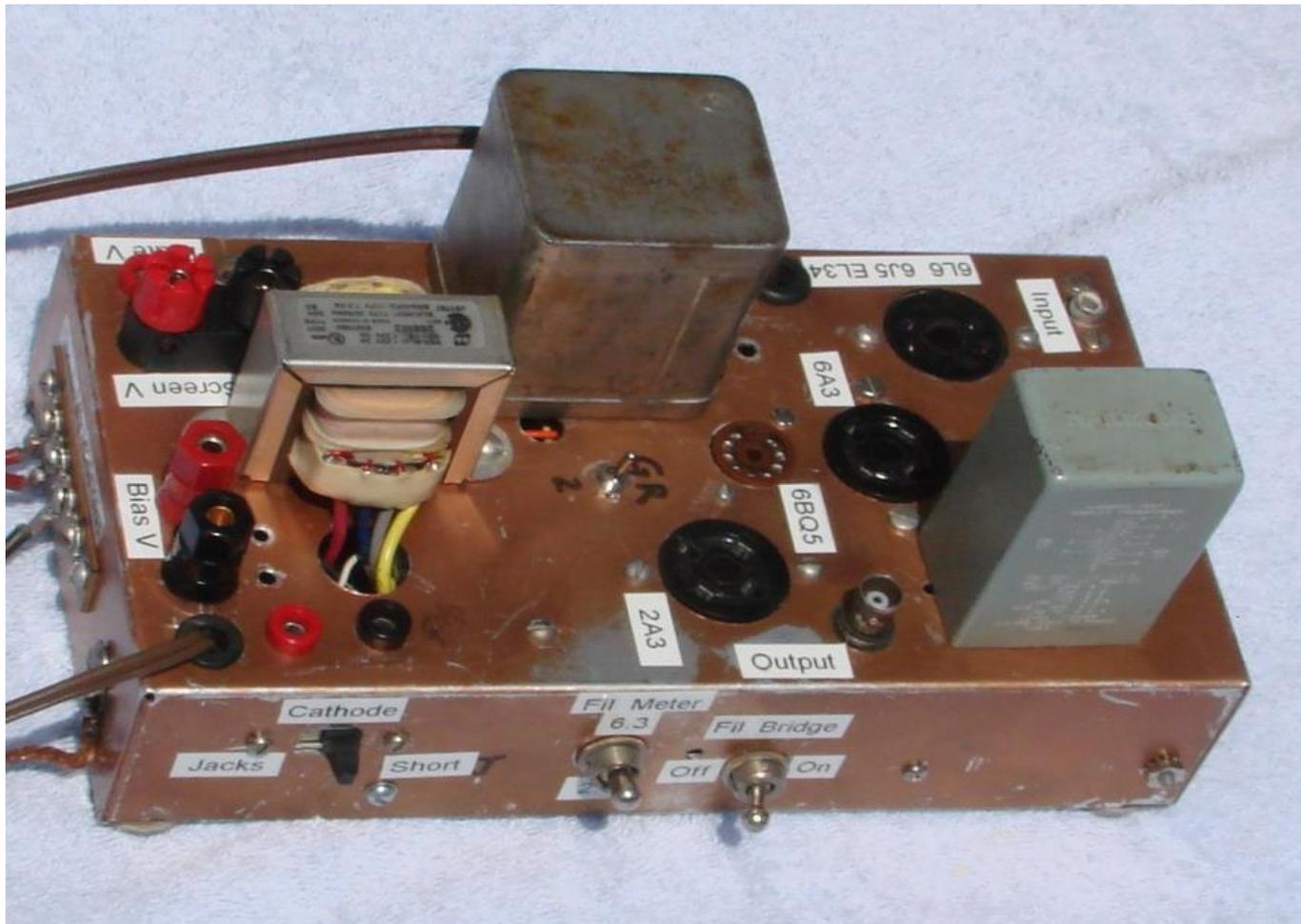
- **Chaos about tube test results**
- **Research the literature and “prior art”**
 - **Engineering teaching texts**
 - **Industry practices, IRE 1950, General Radio, other elaborate testers**
- **Build a “no excuses” tester to verify performance as the manufacturer did**
- **Use that information as a basis for evaluation of other test methods**

Schematic of Lab Tester



Jagundo Tester RadioActivity 2014





Tube Tester Chassis

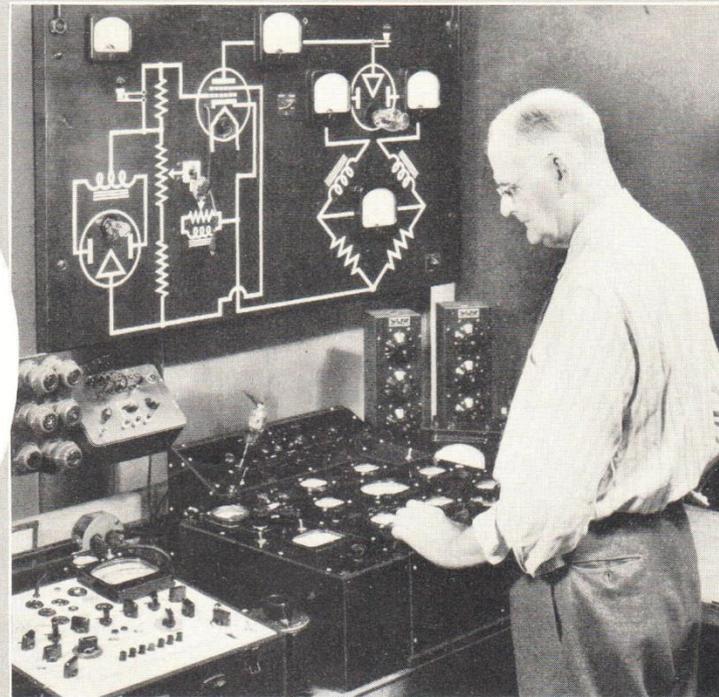
**Filament Transformers and Multiple Socket Detail
not Shown on Schematic**

The Hickok “Genius Circuit” and Legacy

CHOICE OF THE EXPERTS FOR SPEED, ACCURACY and DEPENDABILITY

UNIVERSALLY ACCEPTED

Western Electric	Major Air Lines
Western Union	Major Tube
R. C. A.	Manufacturers
U.S. Signal Corps	Leading Radio &
U.S. Navy	TV Manufacturers
U.S. Air Corps	Technical Schools,
C. A. A.	Colleges, Universities
	Police Departments



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.

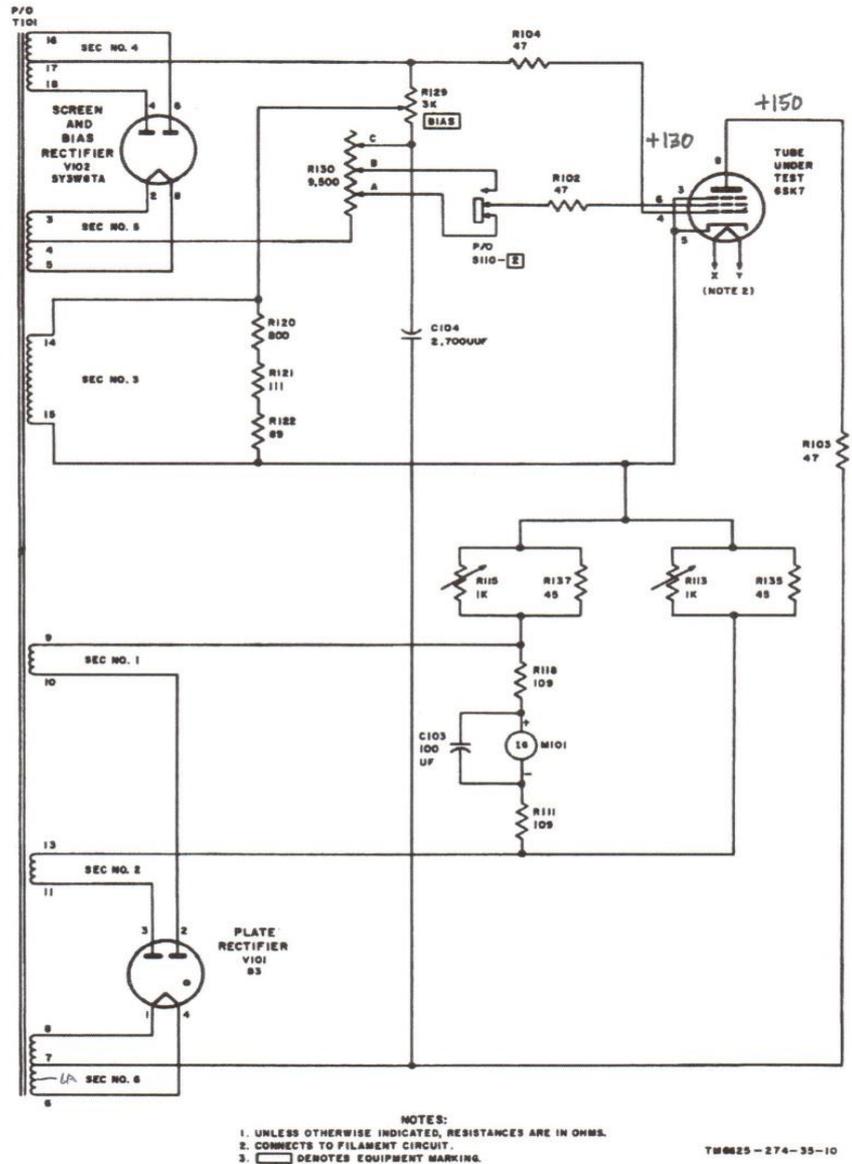


Figure 11. Simplified mutual conductance test circuit, TV-7D/U.

Perspectives on Calibration and the issue of Calibration Tubes

- **Hickok has left many clues as to calibration techniques. They used calibration tubes.**
 - **Adjustments provided in TV-7 series**
 - **Calibration instructions for 6000 and others using shunt pot for transconductance calibration**
 - **Schematic notations in other testers**
- **Use of AC surrogate technique does not require calibration tube, but is 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
- ✓ Glass tubes are fine
- ✓ Many sources offer to sell you a calibration 6L6



Calibration Tube Dilemma

- **Each type of tester is set up differently**
- **Hickok apparently 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**

Selection of a Calibration Tube

- **Hickok testers use the same frequency signal and filament voltage**
- **6L6s can exhibit different tendencies in leaking filament into the signal**
 - **Mike Higgins on Bogey Tubes – Radio Age, January 2015 pgs. 13-14**
 - **Daniel Schoo, others**
- **To separate the ones that do from those that don't, you need to switch the filament connections**

Filament Connections on the TV-7

H-S Format 539B, C, 6000 series

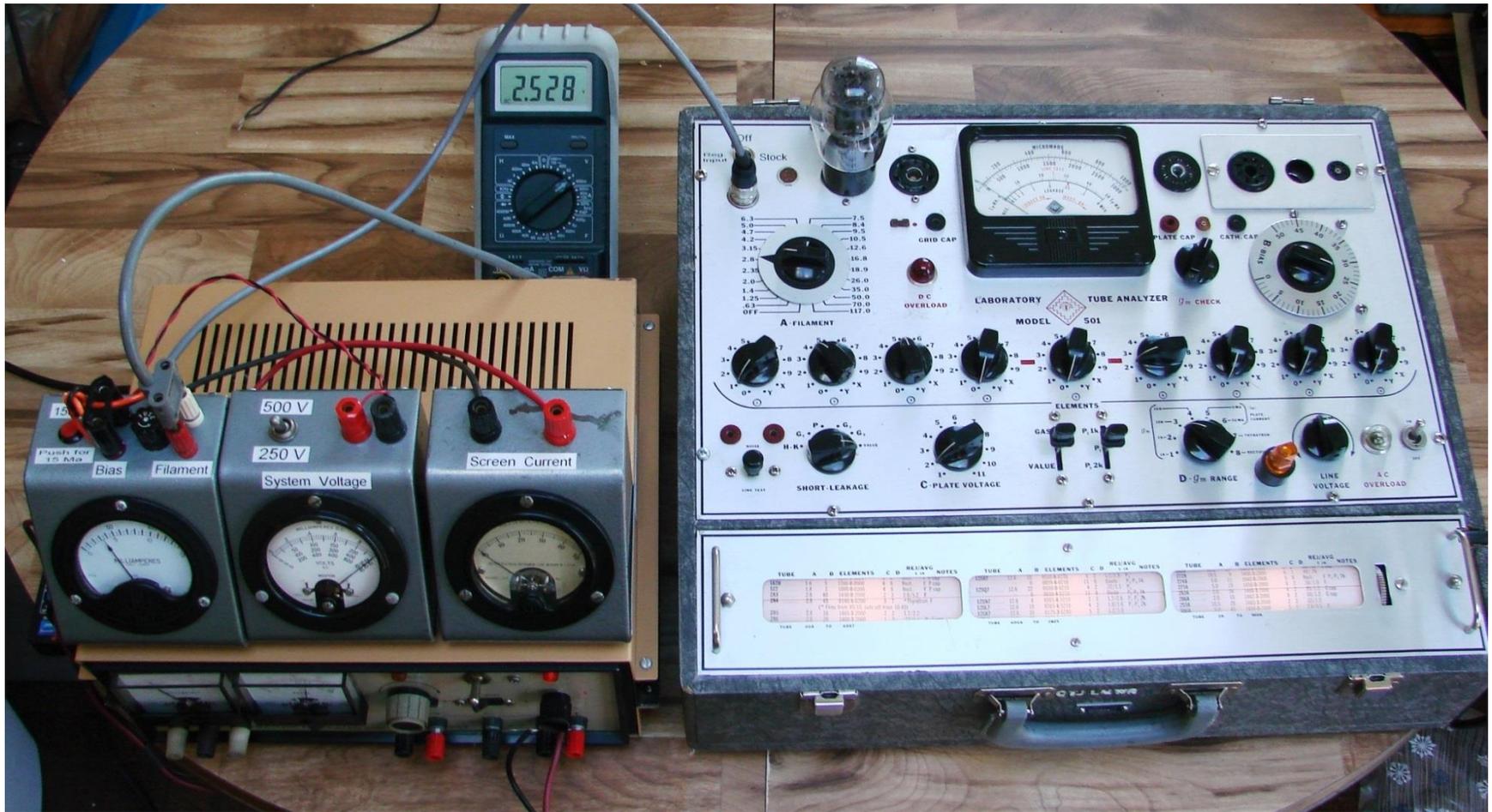
F-R format applies to TV-3, TV-10, 539A, 600, 800, Western Electric
To be sure, look up 6L6 on the roll chart of your tester.

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 for 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**

The Quest for the Ideal Tube Tester



Issues in Regard to Dating Tubes

- **Enormous amount of information is available on tube dating.**
 - **Ludwell Sibley, Bro. Patrick Dowd – RCA Archives**
 - **Lots published, Tube Lore, The Tube Collector**
 - **Many varying locations, not easily accessible**
- **Gaps still exist in our knowledge**
 - **Currently addressing the gap in codes of non-RCA tubes from about 1935 to after WWII**
 - **Sylvania project because I was “seeing things”**

Sylvania Coding System

- **Sylvania had been using a manufacturing date code for many years**
- **Started in 1943 as two digits under the tube ID**
- **1945-46 it was expanded to three**
- **A great help was that Sylvania made lots of tubes for resale by others**
- **This code continued far into the days of open coding adopted in 1946 (until about 1957)**

1943 6F6G

6F6G L3
CHS tube 12/1943



1946 6U7G

6U7G A6M
Sylvania dated 9/1946



1952 Sylvania 2A3 Branded NU

**NU branded 2A3 A2M
January 1952
Early double plate**



**NU branded 2A3 A2M
Base with 1953 13th
week warranty date**



RCA Branded 7A8

RCA 7A8
1951 9th week
Dot = purchased type



RCA 7A8
Sylvania L0B
December 1950



Rare 6D6

A late 1945 Sylvania tube branded Silvertone. Sylvania had started adding the location, but soon went to “3 under”.



Sylvania Inquiry

- **Other than RCA, major gaps exist regarding date coding in this time period**
- **Looking at many manufacturers and resellers is extremely valuable**
- **Best examples are GE (before Ken-Rad acquisition), Philco, Raytheon, Zenith**
- **M-R program is a valuable tool**
- **A chart is needed for easy access to a broad look at tube coding practices in the industry**

Researching the RCA Archives

- **The following information is taken from the TCA Data Cache provided to TCA members in July 2011.**
- **They amount to about 7000 pages, from 37 product management binders from the RCA Archives, obtained by Bro. Patrick Dowd and donated to the Antique Wireless Association.**

PRODUCT NOTICE

PAGE 1 OF 1

45-2

45 changed to purchased type

Source: Sylvania

March 1955

DESCRIPTION <u>Power Amplifier</u>		RCA TYPE NO. <u>45</u>	
FEATURES		INITIAL DEV. NO. _____	
		DRAWING NO. _____	
		PRODUCT LINE CLASS. <u>Receiving Entertainment Class</u>	
PACKAGING DATA		PROG. CHART APPROVAL DATE _____	
BULK _____	CRATE _____	CARTON _____	PROPOSED ANNOUNCEMENT DATE _____
UNIT _____	STD. _____	EXPORT _____	RELEASE SHIPMENT DATE _____
ENGR. RESPONSIBILITY. <u>Harrison</u>		SOURCE: MFD _____ PURCHASED <input checked="" type="checkbox"/>	
QUANTITY _____		PROB. SALES DEMAND. <u>10,000/year</u>	
VOLUME (CU. FT.) _____		% ROYALTY. <u>1.25 RCA</u>	
WEIGHT (LBS.) _____		% EXCISE TAX. <u>yes</u>	
ENCLOSURES		REPORT SALES TO	
BULLETIN _____ INSERT _____ PKG. LIST _____		RCA LABS. _____ RETMA <input checked="" type="checkbox"/> NEMA _____	
		REPORTING CODES: RETMA <u>ER</u> NEMA _____	
LIMITATIONS			
NONE			
COMPETITIVE DATA AND OTHER REMARKS			
Type is being changed to "purchased type" category.			
Purchased source - Sylvania			
PROCEDURAL INSTRUCTIONS INVOLVED			
100.7 _____	204.3 _____	220.8.1 _____	229.1.1 _____
110.5.1 _____	205.1 _____	221.1 _____	301.6 _____
141.1 _____	220.1.1 <input checked="" type="checkbox"/>	225.1.1 _____	510.1 _____
33.14 _____	220.2.1 _____	227.1.1 _____	636 _____
203.2.1 _____	220.3.1 <input checked="" type="checkbox"/>	227.2.1 _____	695 <input checked="" type="checkbox"/>
204.1 _____	220.4.1 <input checked="" type="checkbox"/>	228.1.1 _____	301.13 <input checked="" type="checkbox"/>
THE FOLLOWING ACTION IS REQUESTED			
G. J. Janoff:	Please remove from P.I. 220.3.1. Also please add "purchased" notation in P.I. 220.1.1 and 220.4.1.		
J. F. Maier:	Please purchase quantities to meet sales demand.		
C. W. Taylor:	Please note that type has been removed from P.I. 220.3.1.		
C. W. Springman:	Please hold tools and facilities applicable to this type <u>only</u> for a two year period and then review for scrap.		
J. May:	Please delete from P.I. 695.		
C. O. Hawkins:	Please remove all standardizing notices pertaining to RCA manufacture of this type.		

(A) ADDITION (C) CHANGE (D) DELETION
 ISSUED BY N. F. Mackenzie DATE 3/1/55 ORIG. ISSUE NO. _____
 9 912 11-53
 MANAGER, PRODUCT PLANNING SECTION
 REV. NO. H-680

45-3

Type can no longer be purchased

June 25, 1957

End of an era

PRODUCT NOTICE

COM. TYPE 45
DEV. TYPE _____

PROD. CLASSIFICATION <u>Receiving Entertainment-Class</u>	
DESCRIPTION <u>Power Amplifier</u>	HW RECORD 100K
LIMITATIONS <u>Withdrawn from Line. Type can no longer be purchased.</u>	DSD SLIP FILE 7/5/57
MILITARY BRANDING _____	QUALIFICATION APPROVAL STATUS _____
COMPETITIVE DATA	

ENGRG. LOCATION _____	PACKAGING DATA
APPROVED PROGRAM CHART DATE _____	BULK _____ CRATE _____ CARTON _____
PROPOSED ANNOUNCEMENT DATE _____	
RELEASE SHIPMENT DATE _____	
ESTIMATED SALES DEMAND _____	ENCLOSURES
INITIAL WAREHOUSE INVENTORY _____ DATE _____	BULLETIN _____ INSERT _____ PKG. LIST _____
TYPE APPROVAL SAMPLES _____ DATE _____	
SOURCE-MANUFACTURING LOCATION _____	REPORTING CODE
PURCHASED _____	RETMA _____ NEMA _____ RCAL _____
% ROYALTY _____	
EXCISE TAX _____	
WARRANTEE CODE _____	

SPECIAL ACTION

WITHDRAWN FROM LINE

RECEIVED
JUN 25 1957
STANDARDIZING DEPT

FORM 1912 1-55

ISSUED BY N.F. Mackenzie **DATE** June 25, 1957

PRODUCT PLANNING

9 118519 INITIAL (WHITE)	CHANGE (BLUE)	WITHDRAWN FROM LINE (PINK)
PREVIOUS ISSUE NO _____	CURRENT ISSUE NO <u>H-919</u>	

12AX7-1

- Introduction date in 1947
- "Identical to the 12AU7 except for the grid"
- (plate is not carbonized)
- May 1947

DATA
K.O.D. SLID
G.M.A.K. FILE

Date: May 21, 1947
Development No. A4522A
Commercial No. _____
Eng. Project No. _____

Product Class: Receiving-Miniature

Description: High mu double triode in 9-pin miniature for applications similar to those for the 6SL7GT and 12SL7GT.
Competitive Types: 6SL7GT, 12SL7GT

Date Program Chart Initiated: 3/31-47 Revised: _____ Revised: _____

	COST		Time to Complete (Months)	ESTIMATED	
	Capital \$	Expense \$		By	Date
ENGINEERING	Development	Stdz. Notices	5/1/47		
	Development Equipment	Published data	5/15/47		
	Tube Development		5/15/47	N.H.G.	3/31/47
	Guidance Cost of Tube	\$			
Remarks: <u>Construction of A4522 is identical to the 12AU7 except for the grid (plate is not carbonized)</u>					
MANUFACTURING	Temporary Tools	Temporary facilities are available for testing.			
	Temporary Equipment				
	Permanent Tools	See attached equipment survey.			
	Permanent Equipment	\$3375	4 months	W.L.	4/11/47
	Pilot Production		7/1/47		
	Ready for Regular Prod.		10/1/47		
Temporary Cost of Tube	\$				
Remarks: <u>Factory will produce 500 tubes by September 1, and ship them to the warehouse by September 15, 1947. The A4522 will share 12AU7 facilities.</u>					
COMMERCIAL	Estimated Sales	1st year: 50,000	2nd year: 75,000	3rd year:	
	Warehouse Stock on Announcement Date	500 tubes			
	Maximum Production Capacity Planned	50,000 per year by _____			
	Announcement Date	September 15, 1947			
Remarks: _____					
APPROVALS	Division Engineer	<u>Wallace James</u>	Date: <u>4-15-47</u>	Central Planning	<u>W.H. Myers</u> Date: <u>5-20-47</u>
	Engineering Manager	<u>R. T. Orth</u>	Date: <u>4-15-47</u>	Plant Manager	_____ Date: _____
	Manufacturing Manager	<u>G.W. Crawford</u>	Date: <u>5-20-47</u>	Commercial	<u>K.G. Bucklin</u> Date: <u>5-21-47</u>
	Remarks	Factory Supt.	<u>H.A. Delooy</u>	Date: <u>5-20-47</u>	

cc: Dist. #D

12AX7-2

12AX7A
Superseded
12AX7 in 1960

Cincinnati
manufacture

PRODUCT NOTICE		COMMERCIAL TYPE NO. 12AX7A	
<small>COLOR CODE: Commercial: INITIAL (white); CHANGE (blue); WITHDRAWN (pink); Developmental Type: (yellow)</small>		DEVELOPMENTAL TYPE NO. A40267C	
PRODUCT CLASSIFICATION RECEIVING ENTERTAINMENT - MINIATURE		SW. RECO MAR DATA SL10 FILE 1/4/50	
DESCRIPTION High mu twin triode in 9 pin miniature envelope.			
SALES LIMITATIONS NONE			
MILITARY BRANDING		QUALIFICATION APPROVAL STATUS	
COMPETITIVE DATA Supersedes 12AX7.			
ENGINEERING LOCATION Harrison	SOURCE: MFG. LOCATION ^{SHIFT FROM MAR} Cincinnati		PACKAGING DATA
	PURCHASED		APPROX. SHIPPING WEIGHT
	EQUIPMENT	DISTRIBUTOR	BULK <input type="checkbox"/> CRATE <input type="checkbox"/> CARTON <input type="checkbox"/>
APPROVED PROGRAM CHART DATE	6/9/60		ENCLOSURES
PROPOSED ANNOUNCEMENT DATE	7/8/60	8/15/60	
TYPE APPROVAL SAMPLES			<input type="checkbox"/> INSERT <input type="checkbox"/> PK. LIST
INITIAL WHSE. INVENTORY	NAT'L TOTAL (UNITS) 2,000		<input type="checkbox"/> BULLETIN: DATE
RELEASE SHIPMENT DATE	7/8/60		REPORTING CODE
ESTIMATED SALES DEMAND	Will supersede 12AX7		EIA ER NEMA
EXCISE TAX RATE YES %	WARRANTY CODE- Std. Rec. Ent.		EPRA 71303 RCA
SPECIAL ACTION			
ISSUED BY A. W. JEWELL	DATE ISSUED Harrison 3/30/60 6/9/60	PREVIOUS ISSUE NO.	HE-1217
		CURRENT ISSUE NO.	HE-1214

12AX7-3

- ❑ Interim construction at Harrison only
- ❑ Mid 1960
- ❑ Appears that Harrison was making short cage tubes
- ❑ Apparently marking issues for conversion to the A
- ❑ Don't tell anybody!

12AX7-A

PROGRAM CHART

PRODUCT LINE Entertainment-Receiving Tubes
 NAME OR DESCRIPTION 9 pin miniature, twin triode

COMPETITIVE PRODUCTS
 7025
 12AX7
 6EU7

DEV. NO. <u>440267C</u>	
RCA TYPE NO. <u>12AX7A</u>	
MIL. SPEC. <u>GEN</u>	
DATE INITIATED <u>3-25-60</u>	<u>RECORD</u>
DATE APPROVED <u>3-30-60</u>	<u>MARK</u>
<u>DATA</u>	
<u>3110</u>	

	COST	TIME TO COMPLETE	ESTIMATE	
			BY	DATE
ENGINEERING	LIFE TEST	\$		
	GUIDANCE FACTORY COST (PER _____)	\$		
	DESIGN & DEV. <u>STDZG. NOTICES—MFG. DWGS.—WILL ISSUE</u>		<u>3-29-60</u>	<u>R. Stiles</u> <u>3-25-60</u>
	<u>TEST SPECS. WILL ISSUE</u>		<u>Completed</u>	<u>J. Dean</u> <u>3-25-60</u>
TYPE APPROVAL <u>TECH. DATA FOR PUBL. WILL BE SUPPLIED</u>		<u>Completed</u>	<u>J. Dean</u> <u>3-25-60</u>	
REMARKS	Interim construction for Harrison only to manufacture 100,000 tubes. Construction identical to Harrison's 12AX7 code G-74, manual assembly, short cage. No tooling to be ordered for this interim construction.			
MANUFACTURING	TEMPORARY TOOLS & EQUIPMENT	\$		
	PERMANENT TOOLS & EQUIPMENT	\$	<u>None required.</u>	
	PILOT PRODUCTION WILL START _____			
	REGULAR PRODUCTION WILL START <u>3-21-60</u>			
MAX. PROD. CAPACITY PLANNED <u>48,000</u>		PER month		MFG. LOC. <u>Harrison</u>
REMARKS	A "one shot" deal only. No production beyond 7-15-60. Shipping schedule as follows: by 4-4-60 - 2,000 tubes *Approx. 10,000 of this total will have been branded 12AX7, prior to etch changeover. These are known as 12AX7-G74. by 4-29-60 - 28,000 additional tubes by 5-31-60 - 48,000 " " by 6-30-60 - 21,000 " " by 7-15-60 - 1,000 " " Total: <u>8100,000</u>			
MARKETING	SALES FORECAST <u>100,000</u>			
	WAREHOUSE STOCK REQUIRED <u>2,000</u>		BY DATE <u>4-4-60</u>	
	ANNOUNCEMENT DATE <u>None to be made</u>			
REMARKS				
APPROVALS	APPROVED BY	DATE	APPROVED BY	DATE
	FACT. SUPT. <u>E. Liebmann</u>	<u>3-29-60</u>	PLANT MGR. <u>G. T. Pachman</u>	<u>3-30-60</u>
	PROD. CONTROL <u>J. E. McDonald</u>	<u>3-29-60</u>	QUALITY MGR. <u>R. A. Jacobus</u>	<u>3-29-60</u>
	MFG. MGR. <u>C. P. Miller</u>	<u>3-29-60</u>	ENGINEERING <u>R. F. Dunn</u>	<u>3-28-60</u>
	PLANT MGR. <u>E. J. Lautenschlaeger</u>	<u>3-29-60</u>	EQUIP. DEV. <u>P. L. Farina</u>	<u>3-20-60</u>
REMARKS	Approved except for shipment of 2,000 by March 31. Earliest possible date for 2,000 is April 4, 1960. S. A. Cochrane.			

(A) ADDITION; (C) CHANGE; (D) DELETION.
 SEE REVERSE FOR DISTRIBUTION

ISSUED BY A. W. Jewell 3-30-60
 MARKET PRODUCT PLANNING
W. R. Percival 3-30-60
 OPERATIONS PRODUCT PLANNING

/cpz

12AX7-4

12AX7WA
Release

Early 1964

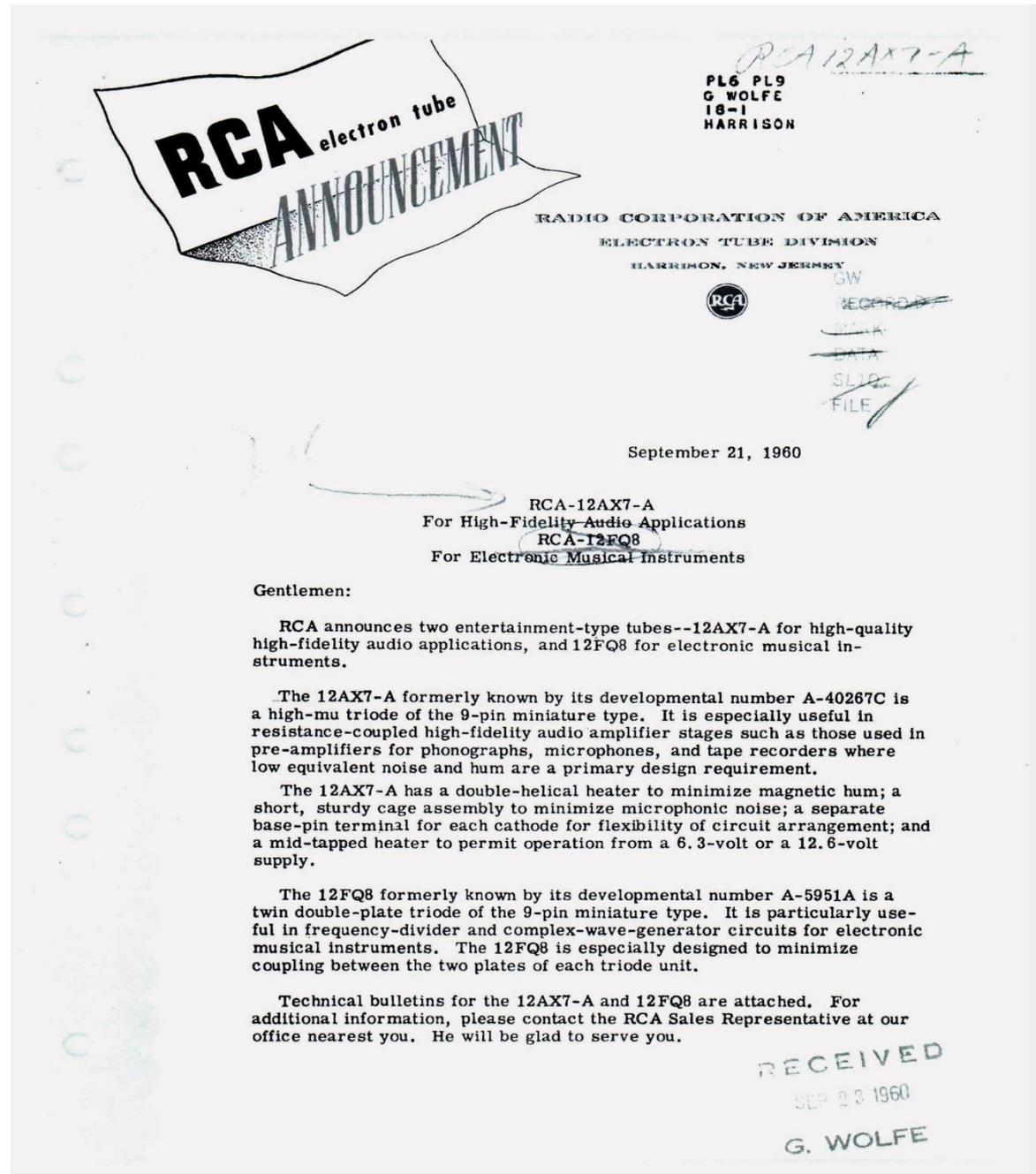
Ruggedized
12AX7

Direct sale to
government
only

PRODUCT NOTICE		(1) COMMERCIAL TYPE NO.
This form should be prepared in accordance with P.I. 212-4		12AX7WA
COLOR: Commercial: INITIAL (white) CHANGE (blue); WITHDRAWN (pink) CODE: Development or Custom Type: (yellow)		(2) DEVELOPMENTAL TYPE NO. AL0362A
(5) PRODUCT LINE (NAME, ABBREVIATION, AND CODE)		(3) PREVIOUS ISSUE NO.
RECEIVING INDUSTRIAL - PREMIUM (111)		(4) CURRENT ISSUE NO. IR-190
(6) DESCRIPTION 9 pin T6½ ruggedized version of 12AX7.		
(7) SALES LIMITATIONS Direct Government only.		
(8) MILITARY BRANDING	(9) QUALIFICATION APPROVAL STATUS	FILE
(10) COMPETITIVE DATA 12AX7.		
(11) ENGINEERING LOC.: HA <input checked="" type="checkbox"/> MA <input type="checkbox"/> WC <input type="checkbox"/> LC <input type="checkbox"/> MT <input type="checkbox"/>	(12) SOURCE: 1 HA <input checked="" type="checkbox"/> 2 IN <input type="checkbox"/> 3 LC <input type="checkbox"/> 4 MA <input type="checkbox"/> 5 CI <input type="checkbox"/> 6 PR <input type="checkbox"/> 7 WO <input type="checkbox"/> 8 MT <input type="checkbox"/> 9 WC <input type="checkbox"/> 0 BF <input type="checkbox"/>	(18) ENCLOSURES <input type="checkbox"/> NONE <input type="checkbox"/> INSERT <input type="checkbox"/> BULLETIN
(13) APPROVED PROGRAM CHART DATE	EQUIPMENT	DISTRIBUTOR
(14) PROPOSED ANNOUNCEMENT DATES REGULAR <input type="checkbox"/> SPECIAL <input type="checkbox"/>	NONE	
(15) INITIAL WHSE. INVENTORIES NAT'L TOTALS (UNITS) - BY (DATE)	26050 April '64	(19) REPORTING CATEGORY NO. EIA AR BDSA 71310 B C D F H S U C F U <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> Indicate Restriction Code above
(16) RELEASE SHIPMENT DATES	April 1, 1964	(20) EXCISE TAX <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO
(17) ESTIMATED ANNUAL SALES DEMAND	120,000	(21) WARRANTY CODE 2
(22) DOES TYPE CONTAIN INTENTIONALLY-ADDED RADIOACTIVE MATERIAL? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>		
(23) SPECIAL ACTION Additional quantities required - May 26,050 June 21,200 July 20,923		
(24) DISTRIBUTOR PRODUCTS APPROVAL	(25) ISSUED BY W. H. CHALMERS	DATE ISSUED Jan. 29, 1964

12AX7-5

- Product announcement
- A has double helical heater to reduce hum
- Short cage assembly to reduce microphonics
- Has anybody ever seen a 12FQ8?



12AX7-6

Internal WEC
letter – testing
12AX7 on
Cardmatics at -1V
bias & 100V

Western: Tubes
don't meet spec. -
by large amount

Manufacturers told
them they had no
complaints. Not
going to fix it.

To: C. Lenke

cc: T. Iannicelli
C. Jones/Western Electric
K. Lardie
F. Ratino
F. Trunk

From: T. A. Hayden

Subject: 12AX7 MEASUREMENTS ON KS CARDMATIC TUBE TESTERS

The problems that have arisen are due to the fact that manufacturers are no longer holding their tubes to published specs. In the published specs two sets of conditions and resultant transconductance values are listed:

1. 250V E_b - 2V bias, 1600 μ mhos transconductance
2. 100V E_b - 1V bias, 1250 μ mhos transconductance

For various reasons we have selected Condition # 2 as a test condition to be used on the cardmatics. Now, it seems, most American manufacturers are only holding the transconductance at Condition #1; and as a matter of fact when measured under Condition #2 with lab standard equipment, tubes of recent manufacture (several different vendors) were found to have transconductance values of typically less than 50% of bogey. Since our cardmatic tube testers are set to reject tubes at 63% of bogey, these recent tubes naturally will read "reject" on the cardmatic testers. Discussions with several vendors and the EIA Office in Washington have not resolved this difficulty.

Essentially the manufacturers state that the published specs are only typical values and not guaranteed; and furthermore, the manufacturers plan to take no action since they have had no complaints from tube customers. Since our major difficulty with this tube have been with Western Electric customers, I forwarded the above information by telecon to:

Mr. C. E. Jones
Western Electric
50 Lawrence
Springfield, New Jersey 07081
(201) 467-7133

Wrap-up

- **Hope you enjoyed the discussion**
- **More to come in the future if desired**
- **Thanks for your attention**
- **Next RadioAge article on tube behavior and testers**
- **For a copy of the slides with color**
PKHartHAVE@aol.com. Use “Timonium” in Subject line.