A Short History of Vacuum Tubes

From about 1930 to the Present

MAARC RadioActivity, June 14, 2024

Paul Hart

Presentation
Limited to Receiving Tubes

and will not address

- **Transmitting Tubes**
- **Tungar Rectifiers**
- **Phanotrons**
- **Cold cathode rectifiers**
- **Mercury-Arc Rectifiers**
- **Gas filled tubes, Thyratrons, Ignitrons, Voltage Regulators**
- **Photocells**
- **Electron Ray Tubes**
- **Cathode Ray Tubes**

Organization

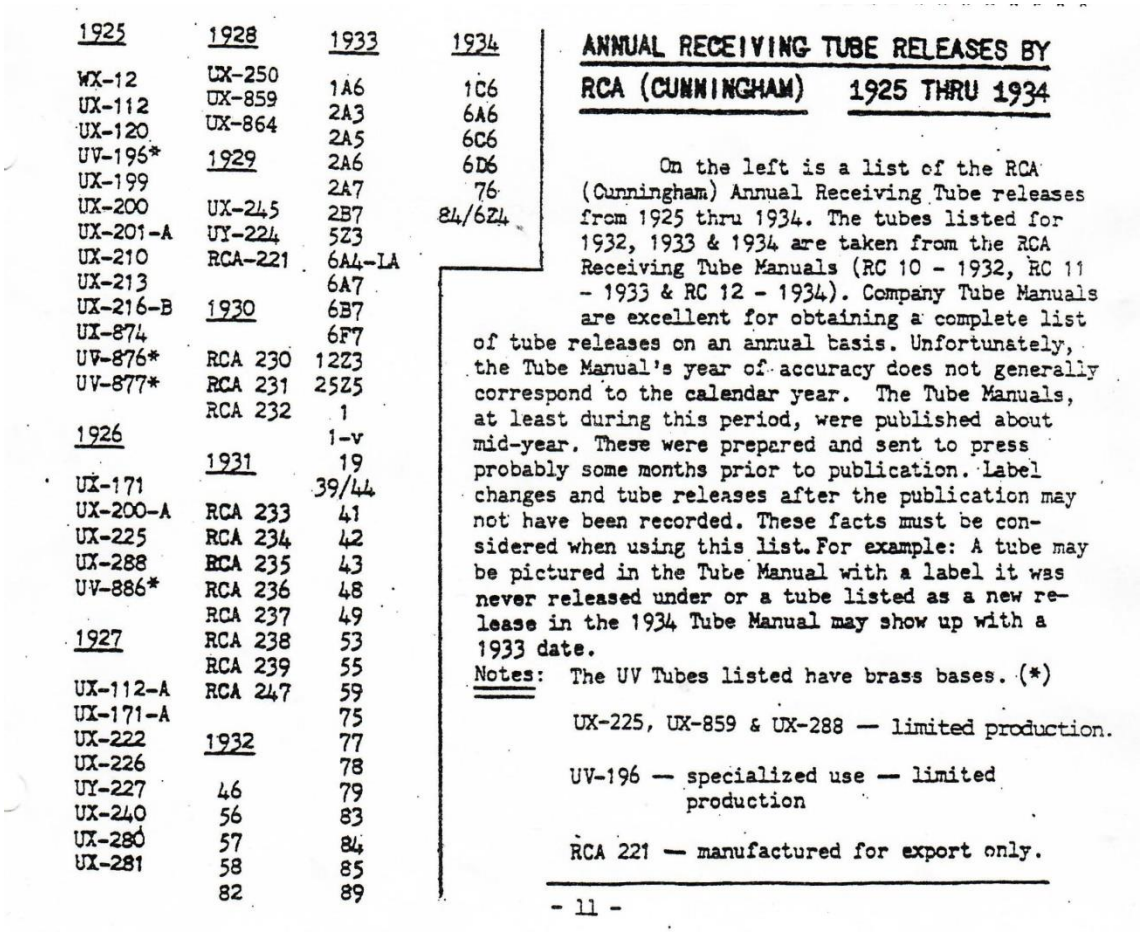
- **Early transition to the “Modern Era”**
- **Joint activity between tube manufacturers and circuit designers**
- **Industry position after WWII**
- **Developments to meet new demands, TV**
- **Radio collection/restoration**
- **The audio craze - High Fidelity and “The guitar guys”**
- **Recent developments**

RCA(Cunningham) Tube Releases (by year)

Personal Perspectives:

- **"Modern Era" started in 1927, introduction of the 27 and 80**
- **RCA held the superhetrodyne patents and refused to license it to other manufacturers**
- **In 1930, in response to an anti-trust suit, RCA began licensing.**
- **1931 was the beginning of development of superhet and tubes to establish the modern circuit**
- **1932 was the beginning of massive releases. By about 1935, the basic modern receiver design had been established.**

From paper presented by Bro. Patrick Dowd at AWA. Sept 1978



ANNUAL RECEIVING TUBE RELEASES BY RCA (CUNNINGHAM) 1925 THRU 1934

On the left is a list of the RCA (Cunningham) Annual Receiving Tube releases from 1925 thru 1934. The tubes listed for 1932, 1933 & 1934 are taken from the RCA Receiving Tube Manuals (RC 10 - 1932, RC 11 - 1933 & RC 12 - 1934). Company Tube Manuals are excellent for obtaining a complete list of tube releases on an annual basis. Unfortunately, the Tube Manual's year of accuracy does not generally correspond to the calendar year. The Tube Manuals, at least during this period, were published about mid-year. These were prepared and sent to press probably some months prior to publication. Label changes and tube releases after the publication may not have been recorded. These facts must be considered when using this list. For example: A tube may be pictured in the Tube Manual with a label it was never released under or a tube listed as a new release in the 1934 Tube Manual may show up with a 1933 date.

Notes: The UV Tubes listed have brass bases. (*)

UX-225, UX-859 & UX-288 — limited production.

UV-196 — specialized use — limited production

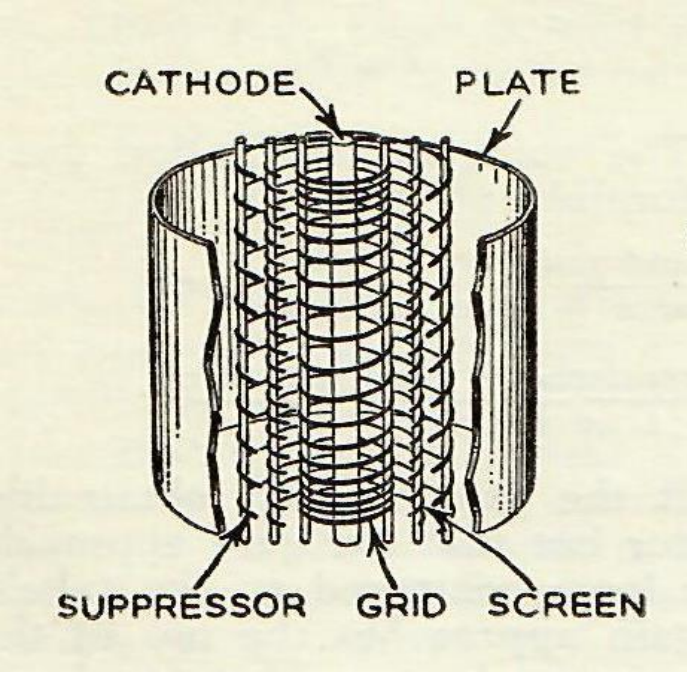
RCA 221 — manufactured for export only.

1925	1928	1933	1934
WX-12	UX-250	1A6	1C6
UX-112	UX-859	2A3	6A6
UX-120	UX-864	2A5	6C6
UV-196*	1929	2A6	6D6
UX-199		2A7	76
UX-200	UX-245	2B7	84/6Z4
UX-201-A	UY-224	5Z3	
UX-210	RCA-221	6A4-LA	
UX-213		6A7	
UX-216-B	1930	6B7	
UX-874		6F7	
UV-876*	RCA 230	12Z3	
UV-877*	RCA 231	25Z5	
	RCA 232	1	
1926		1-v	
	1931	19	
UX-171		39/44	
UX-200-A	RCA 233	41	
UX-225	RCA 234	42	
UX-288	RCA 235	43	
UV-886*	RCA 236	48	
	RCA 237	49	
1927	RCA 238	53	
	RCA 239	55	
UX-112-A	RCA 247	59	
UX-171-A		75	
UX-222	1932	77	
UX-226		78	
UY-227	46	79	
UX-240	56	83	
UX-280	57	84	
UX-281	58	85	
	82	89	

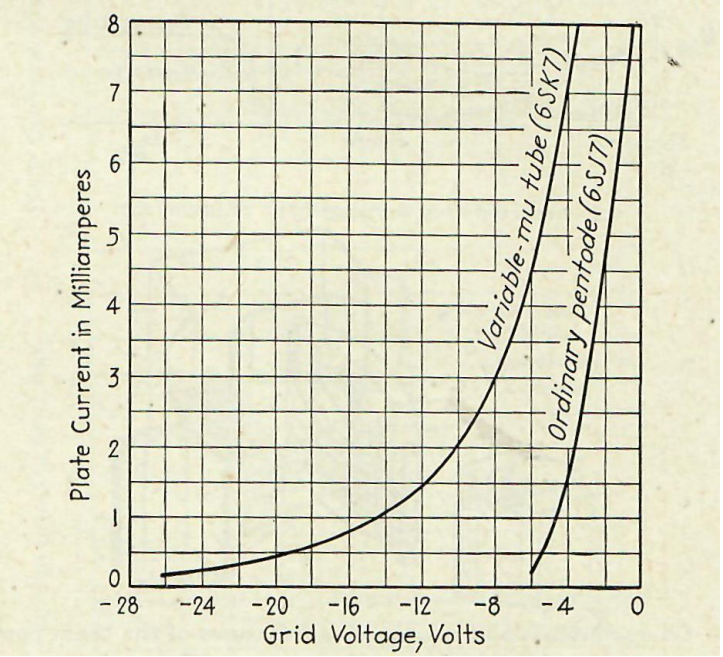
Great Advance for AVC

"Super Control" – Variable mu pentode

Note non-uniform winding of the control grid



Delayed cutoff of the variable mu tube allows for smooth AVC operation



End of “Prehistory” (Sibley)

- **Prior to 1934, manufacturers assigned their own designations to tubes**
- **Created chaos, only voluntary industry uniformity in numbering**
- **1934, the industry established the Radio Manufacturers Association (RMA) to assign designations and be the repository for listed tube characteristics.**
- **Many tube manufacturers continued within specific designations, many of which were widely accepted e.g., RCA 8xx, 16xx, etc. Syl. 12xx, Raytheon RK-xx**

Acorn Tubes

Early tube development for VHF-UHF frequencies. Small size of elements to reduce capacitance and inductance made them suitable only for small signal applications.

Most often seen variants

- **954 pentode**
- **955 triode, March 1935**
- **956 remote cutoff pentode**
- **9004, 9005 UHF diodes**

Miniature tubes introduced in 1939 generally displaced new application of Acorns. Later resurrected as miniatures 9001, 9002, 9003, 9006

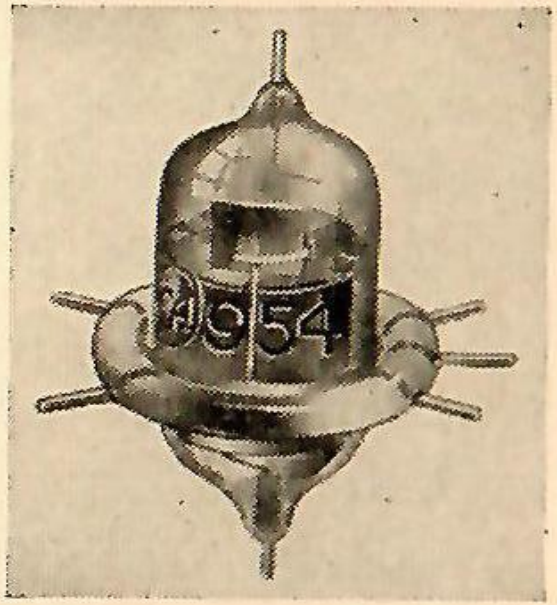


FIG. 14.10.—An acorn type pentode for use as a r-f amplifier and detector at frequencies as high as 425 Mc.

RCA Announcement of "New all-metal radio tubes" 1935

First types:

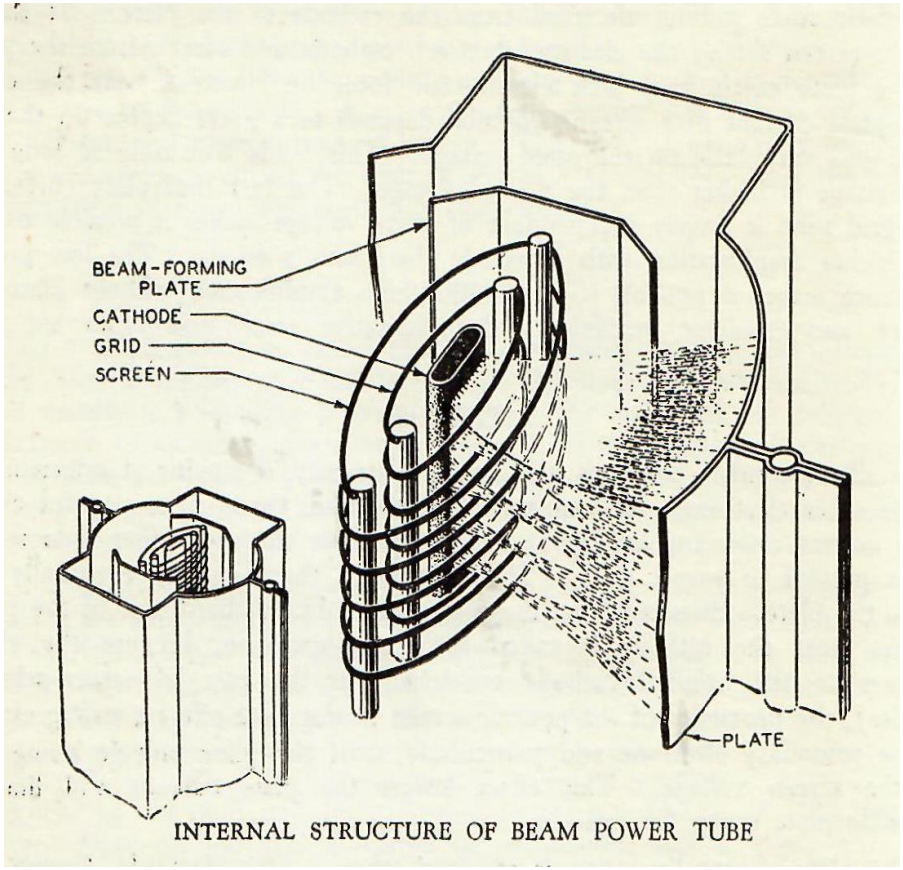
- **5Z4**
- **6A8**
- **6C5**
- **6F5**
- **6F6**
- **6H6**
- **6J7**
- **6K7**
- **6L7**

The Beam Power Tube

- **Developed in Europe, initially thought to be too expensive to manufacture by M-OS**
- **Shared with RCA – resulted in the 6L6 1936**
- **G.E.C. released the KT66 in 1937**
- **David Rossetti presentation on MAARC website, Past Events, Monthly Presentations**
- https://maarc.org/wp-content/uploads/simple-file-list/Monthly_Mtg_Presentations/Beam-Power-Tubes.pdf

Beam Power Tetrode

- **Note that the cathode is not round, but oblong.**
- **Electron flow in a sheet with tightly controlled tolerances between the control and screen grids.**
- **This basic design fostered a basic power tube structure that endures to this day.**
- **More on use of these tubes and variants in Audio Craze section.**



INTERNAL STRUCTURE OF BEAM POWER TUBE

Introduction of new Tube Types

- **May 1938, Sylvania introduced the first "Lock-In" tube, the 1231-later 7V7. Registration of new types ended in 1947.**
- **A predecessor to the button base widely used later on**
- **Some tubes, e.g., 7F8 took advantage of lower capacitance and inductance to reach higher frequencies**

Sylvania News

MARCH-APRIL, 1942 EMPORIUM, PENNA. Vol. 9, No. 8

LOCK-IN—A STUDY IN RADIO TUBE QUALITY

9 POINTS OF MERIT

1. **Lock-In Locating Lug...** also acts as shield between pins.
2. **No Soldered Connections...** all welded for greater durability.
3. **Short, Direct Connections . . .** fewer welded joints—less loss.
4. **All-Glass Base. . .** low loss and better spacing of lead wires.
5. **No Glass Flare. . .** unobstructed space for internal shielding.
6. **Improved Mount Support....** ruggedly mounted on all sides.
7. **Getter Located on Top . . .** shorts eliminated by separation of getter material from leads.
8. **No Top Cap Connection. . .** overhead wires eliminated.
9. **Reduced Overall Height . . .** space saving.

Lock-In, the radio tube that incorporates basic improvements of class tube design and construction, is now doing a high quality radio reception job in millions of home and automobile radios. We want you to know about the nine special points of radio tube improvement found in Lock-In because every day you will encounter more of these tubes in your radio set servicing work.

With set curtailment now a reality, you'll soon start getting the newer models in your shop along with the older ones and that's your opportunity to show your stuff. Let customers know that you're hep to the latest radio tube developments by showing them the difference between old style glass and the new improved Lock-In radio tubes.

Millions of sets in all categories are Lock-In equipped. This new tube design is found in low-drain battery portable sets, automobile sets and in AC-DC home radio sets. In television and frequency modulation you'll find Lock-In proudly doing the finest job possible. Its electrical advantages were worked out with expert engineering eyes focused on high frequency applications. The result of these farsighted efforts (design for Lock-In was initiated as far back as 1936) is the appearance of Lock-In in the fore-front of high and ultra-high frequency applications. Lock-In is a mechanically stronger tube; electrically more efficient. Its name emphasizes one feature which is of increasing importance in modern radio design and particularly in automotive and aeronautical sets—a method of locking tube to socket so solidly that heavy shocks and jars won't separate them. Yet, an easy tilt of the tube with the hand, or using the Sylvania Lock-In Tube Puller, removes the tube as easy as tipping your hat.

More important than the lock-in feature, however, is the real advantage—greater mechanical strength. Support rods are made stronger and thicker. There are fewer welded joints and no soldered connections. Elements are locked in a new, stronger mount assembly that reduces warping and weaving of the elements when the going gets tough. Besides these notable mechanical merits are the improved electrical characteristics. Bringing element leads directly down through the low-loss glass header to become sturdy socket pins accomplishes a much desired reduction in lead inductance and inter-

Introduction of New Tube Types

- **November 1939, RCA introduced the first min. tube types, 1R5, 1S4, 1S5, 1T4. 34 by war's end.**
- **The lighthouse triode 1940**
- **Subminiature tubes**
- **Novar 1946 (12AU7 first)**
- **Button stem octal 1950**
- **Nuvistor 1959 – new types to 1967**
- **Compactron 1961**
- **Novar late 1961 (7868 was the first)**

Accelerated Technological Developments Driven by WWII

- **WWII - the “First Technological War”**
- **Demands for specialized communications – both in quantity and at higher frequencies**
- **Huge developments in radar triggered before the war by the cavity magnetron**
- **Development of the VT Fuze**
- **Demand for electronics by domestic industry for wartime expansion**

Development of the 6AK5 by Western Electric in 1943, Radar IF Amplifier

Three Successive Generations

The one on the right is notable that it weighed only 9 ounces, had 100 dB gain with a 2 MHz bandwidth, and was completely stable with no adjustments. Of particular importance was the low noise 6AK5 used in the smallest amplifier. Use of the 6AK5 became the standard in all US and British WWII radars.

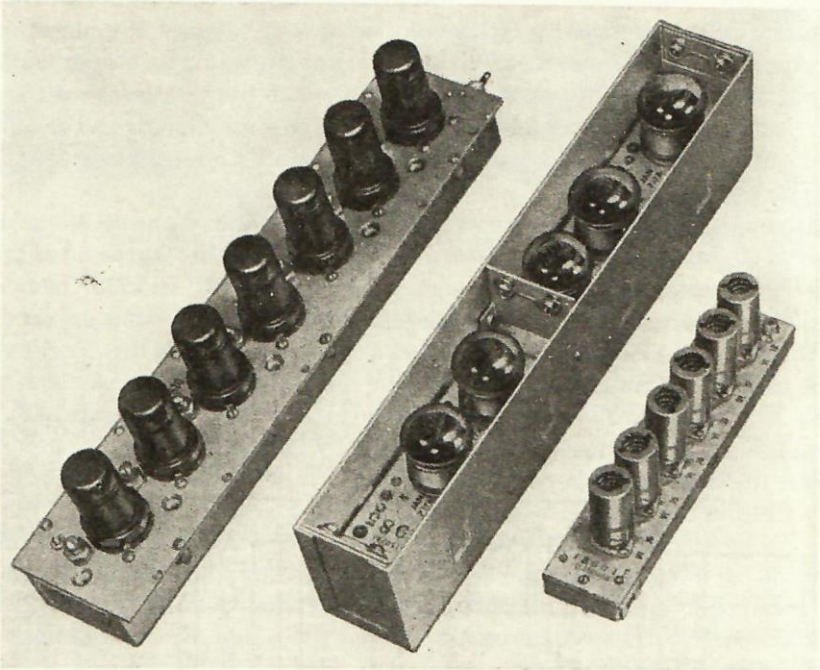
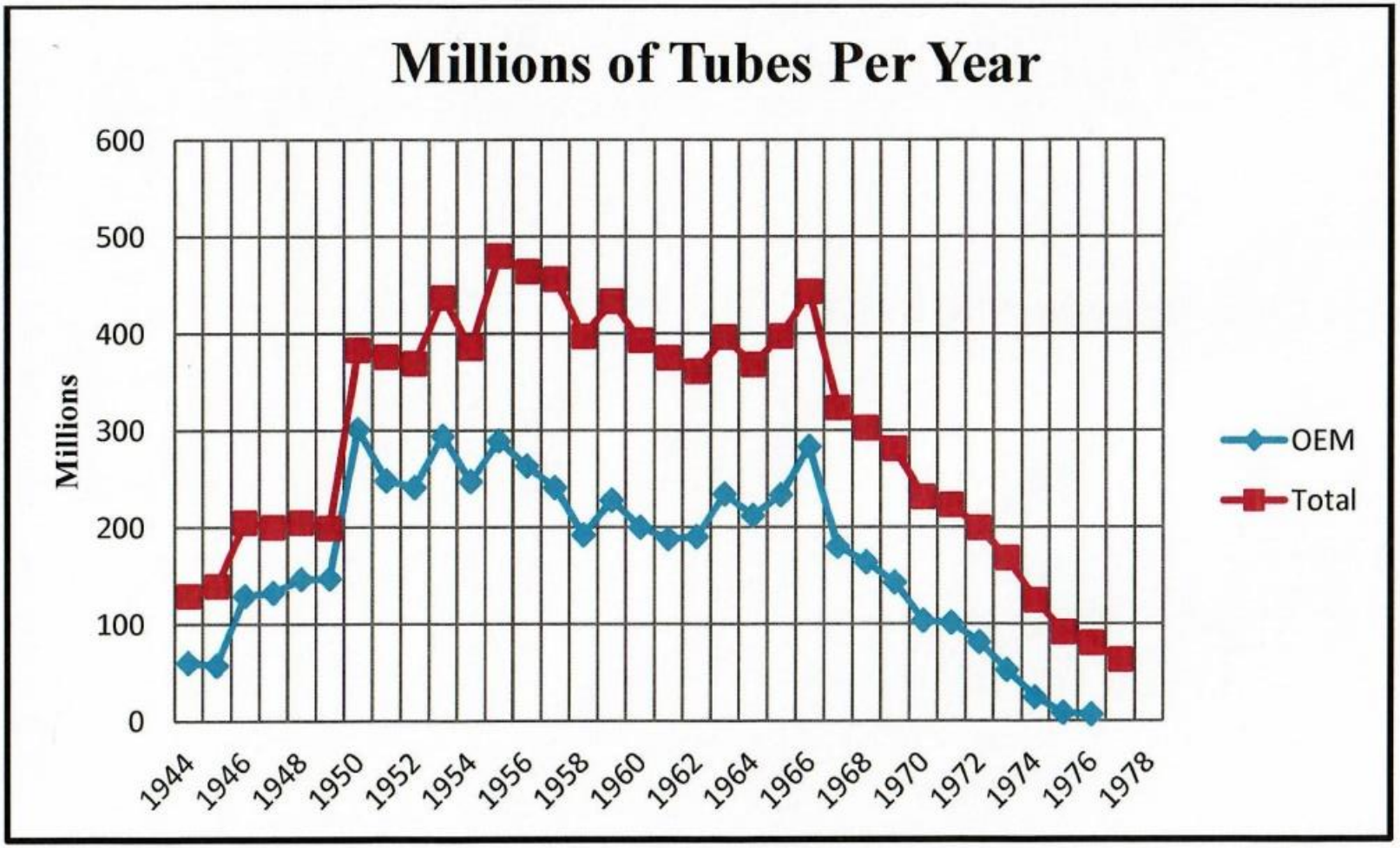


Fig. 2-18. Three generations of IF amplifier designs for military radar applications.

US Vacuum Tube Production
1944 to 1978

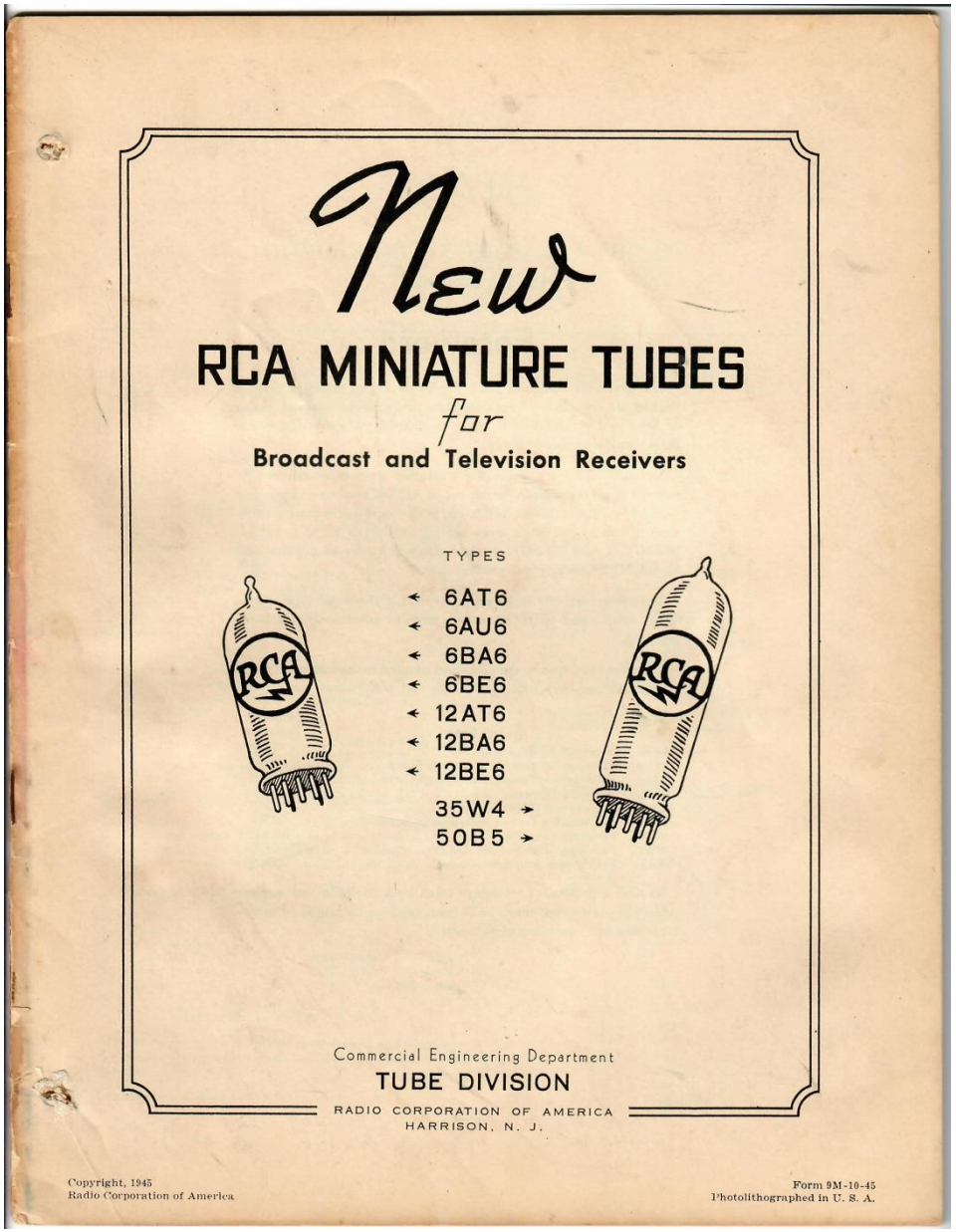


Post War Reorientation of the Electronics Industry

- **Demand for new radios, television**
- **Atomic energy research, national air traffic control, missile defenses, additional commercial communications systems**
- **FM radio broadcasting**
- **1955 was highest domestic tube production**
- **New production facilities**
- **Importation of tubes from overseas, Japan, Europe began to erode US dominance**

RCA 1945 Announcement

- **Recommendations and larger form equivalents also specified**
- **9 types announced with “Tentative Data”**



Adoption of Television

- **Initially, TV receivers used existing tube types.**
- **The race for larger screens, circuit improvements increased demands on tubes**
- **New types and improvements to existing designs were introduced**
- **Color TV created a second “bump” in demand**
- **Transistors and imports reduced and virtually eliminated demand for US tubes**

Sylvania Publicity

New Higher Current 5U4
5U4GB Button Base, New Envelope

Sylvania's New High Current 5U4GB

Sylvania has now developed a truly long-life service-designed tube to relieve the strain on one of the most over-taxed sockets in large screen television receivers. The type 5U4GB high current full-wave rectifier may replace the Type 5U4G, with no wiring changes. The improved tube, along with the new attractive *yellow and black* Sylvania carton, is shown in Figure 1.

By using radically new and better structural design, Sylvania tube design engineers were able to make a receiving tube full-wave rectifier which has higher ratings, better heat dissipation and lower tube drop than the 5U4G without changing the filament requirements (see Figure 2).

The new 5U4GB has a large T-12 bulb which is narrower (1 5/16") than the 5U4G (2 1/16") in its largest dimension. Also, the seated height of the 5U4GB is shorter, 4 3/4", as compared to 4 3/4" for the older type (see Figure 3). Yet, the heat dissipation is improved, because of the wafer stem and new plate design.

Even though a T-12 bulb was used, the same medium shell octal socket was retained on the new tube so that no difficulty with socket clamps will be experienced.

A stronger tube mount was made possible by using a wafer stem construction rather than the old flat press stem construction. A comparison of these two types of stems is shown in Figure 1 of *The New Sylvania 6BQ6GTA Horizontal Output Tube*, elsewhere in this issue. The stem is the bottom of the glass tube envelope along with the leads that make internal connection to the tube mount. On a wafer stem, the leads are arranged in a circle so that there is direct support of the mount by the tube's base.

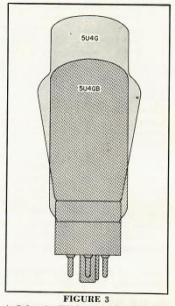


FIGURE 3
A Sylvania 5U4GB superimposed on the 5U4G. The 5U4GB utilizes the modern T-12 bulb (12/8" in diameter) which gives the greatest glass surface area in the smallest possible space for better cooling.

COMPARISON CHART OF THE 5U4GB TO THE 5U4G

5U4G	Sylvania's 5U4GB	Resulting Improvement
Construction		
Flat Press Stem	Wafer Stem	Eliminates stem electrolysis and also provides stronger mount construction. Permits increased ratings.
Regular Plate—ST16 Bulb No Bottom Mica	Redesigned Bottom Mica	Improves filament alignment and reduces internal arcing.
	5U4G	**Sylvania's 5U4GB**
Typical Operation		
R.M.S. Voltage Per Plate	450	450 Volts
Max. D C Output Current	225	275 Ma
Peak Plate Current Per Plate	675	1000 Ma

FIGURE 1
The new, Sylvania developed, 5U4GB will be shipped in the redesigned, distinctive yellow and black tube carton—the calling card for the high Quality Sylvania tube inside.

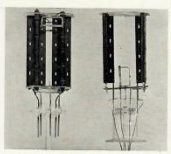


FIGURE 2
Tube mount and stems for the Sylvania Type 5U4G, on the right, and 5U4GB, on the left. Notice the two supporting (top and bottom) micas on the 5U4GB and more rugged overall appearance.

TV Receiver Rectifier Operation

Inasmuch as the power supply is the keystone to set operation, the rectifier tube might be considered the most important tube in the set. Television receivers with picture tubes that are 17" or larger require high current from the low voltage rectifier which taxes the capabilities of any of the older full-wave rectifiers. As a result of this, the rectifier may burn out or merely lose emission capabilities which will result in reduced D C supply voltage.

The new Sylvania Improved Service 5U4GB has a current rating of 275 Ma at 450 Volts output to the capacitor input filter. This extra margin over the 225 Ma for the older prototype will relieve many of the problems now surrounding the Type 5U4G. It is a universal replacement tube which will also find use in high power amplifiers, radio transmitters and other equipment requiring a high current full-wave rectifier.

Improved 6CD6

THE SYLVANIA IMPROVED SERVICE 6CD6G

In the television horizontal output tube family the 6CD6G is popular where exceptionally high plate current is demanded. This tube has successfully stood the demands of modern television for over five years in large screen receivers. Even though this tube has a good reputation, Sylvania, in its improvement program to reduce service call-backs, has made discrete changes in the 6CD6G design (see Figure 1).

Arcing

Arcing may occur at the tube socket, base, or between elements, and, if it occurs, will most likely be where elements are in close proximity and a high potential exists between them. In the older 6CD6G, a critical arc-over point existed between the square beam confining plate and the rounded anode plate at the corners of the beam confining plate. Not only was the voltage gradient higher at these corners, but it is a well-known physical fact that irregular or pointed surfaces have a greater propensity to arc-over than a smooth surface. The offending arc gap is eliminated in the new 6CD6G by squaring off the anode plate so that the corners of the anode and the beam confining plate coincide. Figure 2 illustrates the two conditions; notice how much more space is furnished by the new plate.

Arc-overs may also occur across the micas between electrodes where there is a high voltage potential. Considering that the peak positive plate voltage of the 6CD6G is 6600 volts, it is readily apparent that the insulating properties of materials used have to be pretty good. The new Sylvania Type 6CD6G is utilizing a specially coated mica that not only reduces arcing but also improves horizontal sweep stability. These improvements are due to a reduction in leakage resistance across the mica.

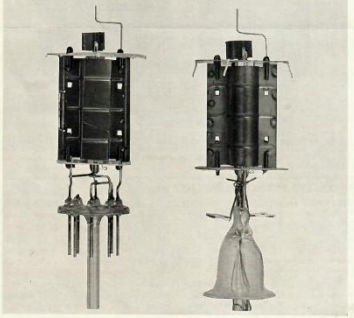


FIGURE 1
Tube mount and stem for the Sylvania Type 6CD6G, old style on the right and new style on the left. The old style uses flat press stem construction and the new style uses the shorter, stronger and more efficient wafer stem.

While every precaution is taken during manufacture of the tube to assure against the presence of foreign materials within it, an extra precautionary measure is taken with the new 6CD6G. A 25 kilovolt spark is applied across the tube pins for positive proof that no troublesome particles exist that could cause arcing.

Glass Electrolysis and Electron Bombardment

Glass electrolysis (chemical decomposition) in an advanced state and high velocity electron bombardment will eventually allow the atmosphere to seep into the glass envelope which will have a catastrophic effect on tube operation. The vacuum tube is a critically balanced electro-chemical device which depends upon a high vacuum for existence. Once air enters the bulb, chemical reaction between the gases and materials will soon result, causing erratic operation and finally complete breakdown.

Electrolysis is reduced by lower temperature and longer conduction paths between electrodes — both features of the wafer stem.

One method of reducing electron bombardment is shielding the glass envelope from the electron stream

(Continued to page 8)

The Audio Craze

- **The term High Fidelity had been used as early as the Zenith Stratosphere in 1935.**
- **The 2A3, was termed by Vacuum Tube Valley and Kittleson as "The Mother of High Fidelity" It was the last industry offering of a large power triode (exception the WECo 300A, B) in the triode power output sweepstakes. 845 and 211 were transmitting tubes.**
- **The 6L6 was a major advance, Zenith started using them in 1937.**
- **RCA began pilot production of the 6L6GC in October 1959, closest thing to the KT-66 of 1937.**
- **What many identify as a kickoff of the High Fidelity audio craze was the Williamson amplifier**

The Original DTNW Circuit

1. **Four stages, input voltage amplifier, phase splitter, driver, and output, all triodes**
2. **Output biased for Class A**
3. **High quality output transformer. Primary 100H min, max leakage inductance 30 mH**
4. **20 dB of feedback taken from the output secondary to the cathode of the first stage.**

The Classic Original.

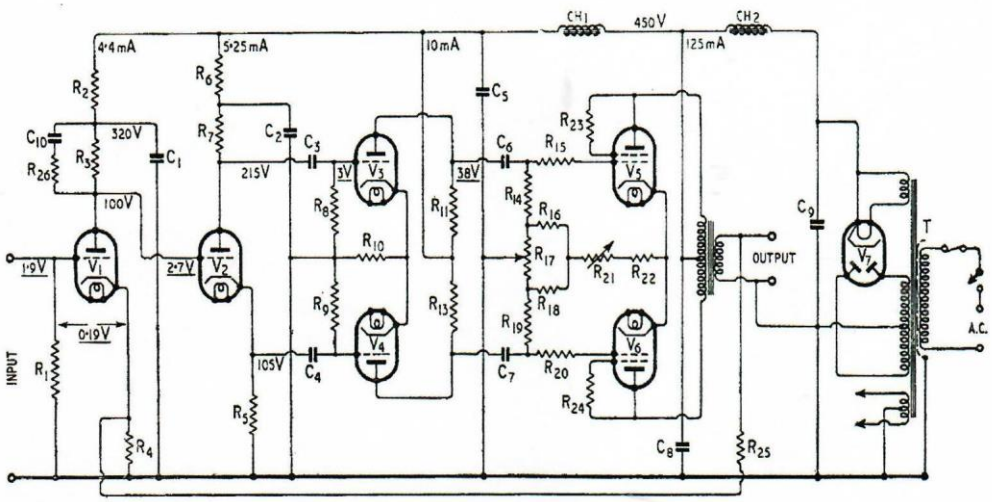


Fig. 1. Circuit diagram of complete amplifier. Voltages underlined are peak signal voltages at 15 watts output.

1947-9. The original circuit for Williamson's amplifier as published by *WIRELESS WORLD*. Triode connected push pull KT66 output with 20dB feedback. An output transformer of the highest quality is an integral requirement of the design.

Many derived types which followed, often loosely called "Williamson-type" amplifiers, embody only some of its features and may or may not be very good amplifiers.

Reconstructed Original Williamson

1949. A superbly constructed ***Williamson*** amplifier of the early format using four type 6J5 valves for the input stages, made by Rogers Developments, England.

Access to High Quality Audio Sources

- The LP disc in 1948
- Open Reel Tape
- Stereo LP Disc in 1957
- CD in 1982
- Recent resurgence in demand for vinyl records

This Changed Everything in the US

Technics SL-1200

Ampex Open Reel Machines

Half track mastering quality
600 with 620 May 1954

F4460 “prosumer” ¼ track stereo
Open reel record/playback 1963

Demand for Higher Power

- **The “pure” Williamson delivered only 15 watts of power, newer speaker designs required higher power with low distortion**
- **David Hafler and Herb Keroes formed Acrosound in 1949 to manufacture high quality transformers**
- **Patented the Ultra-linear circuit in 1952. (Ed Blumlein 1937)**
- **Hafler and Ed Laurent formed Dynaco in 1955.**
- **This development was combined with the original Williamson circuit, then modified (6AN8→7199)**
- **Long term disdain on the part of many for transistorized audio equipment for High Fidelity**

Accelerated Demand for Amplifiers and Tubes

Acrosound Sales of Transformers

1959 Acrosound Advertisement

Acrosound UltraLinear II Amplifier

McIntosh

- **The company was co-founded in 1949 by Frank H. McIntosh & Gordon Gow.**
- **The Unity Coupled Circuit, patented at the brand's inception, is still used today with vacuum tubes which “helps to impart a lifelike warmth and soul to the sound”.**

The McIntosh MC-75 Limited Edition was released in 2000

New Businesses Created
Many New Companies/Products

- **Hafler (est. 125,000 MK III, 400,000 Stereo 70)**
- **Fisher Radio (est. 100,000 500C)**
- **Harmon-Kardon**
- **Altec Lansing**
- **HH Scott**
- **Marantz**
- **McIntosh**
- **Bogen**
- **Heath (est. over 30,000 W5M)**

This Interest in High Fidelity created new demand for specialized tubes

- **US tube designs**
  - **5881 (6L6WGTB) Tung Sol 1950 uprated to 23 W**
  - **6550 Tung Sol, 42 W 1954**
  - **6L6GC RCA 30W 1959**
  - **7591, 7868 novar, Westinghouse, 19 W 1960**
  - **8417, Westinghouse, 35 W 1963**
- **Foreign tube designs**
  - **KT66 Genalex (M-OV) 25W 1937**
  - **EL34, Philips, 25 W, earlier EL37 Blackburn Mullard**
  - **KT88 Genalex (M-OV) 42W 1956**
  - **12AX7 (Telefunken Berlin, Ulm, Mullard Blackburn, Philips Bugle Boy Heerlen)**
  - **The superlative Russian KT-120**

The Kings of British Power Tubes

Genalex was the US marketing name for G.E.C.

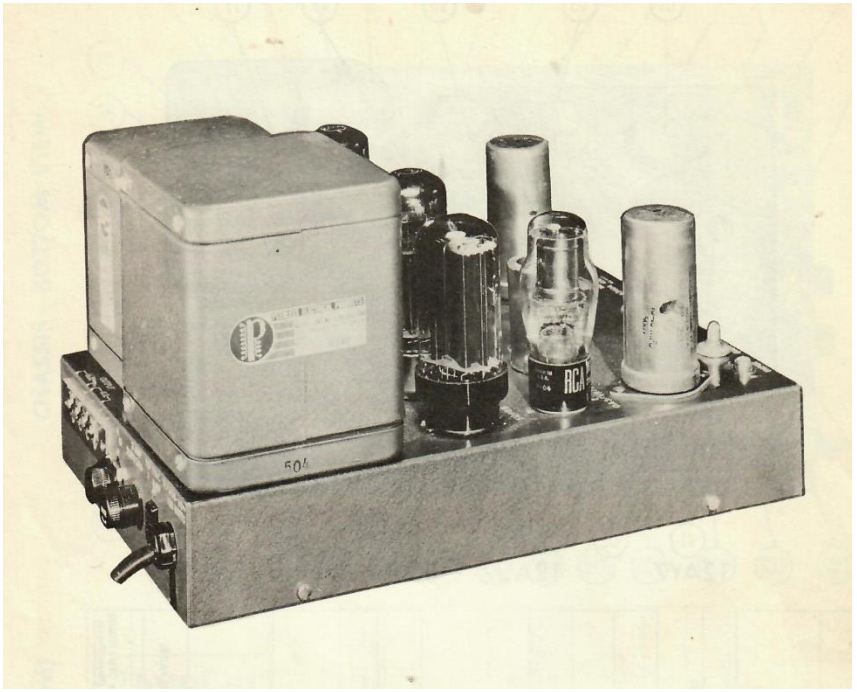
Genalex KT66

Genalex KT88

More American Activity

Marantz 8B
(1961-62?)

Altec 340A (1955)
First Commercial
Use of T-S 6550



One of the Last 6550A run
June 17, 1993

But Wait, There's More!

The 300B Reborn

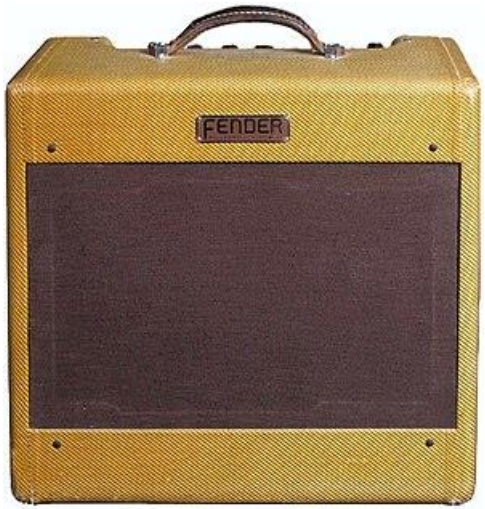
Charles Whitener
CEO (New) Western Electric
Rossville, GA

More Yet: The Guitar Guys

- **Electronic amplification for guitar players has been an issue since the early 1930s.**
- **Tremendous demand for electronics to satisfy the guitar craze. Many performers prefer vacuum tube sound and distortion from overdriving amplifiers**
- **Recent lookup identified 92 active guitar amplifier manufacturers**

Fender Amps/Speakers

Fender Delux 1953



A Fender Bassman amp head with a 15”speaker cabinet

Some Others

4 ElectroHarmonix KT88 power tubes inside a Traynor YBA-200 bass guitar amplifier

Mesa-Boogie “Mark IV” - a guitar combo amplifier

High Quality Audio and Guitar Amplifiers

- **Both classes of amps require many of the same tube types**
- **With some exceptions, the new old stock tubes are considered most desirable by the audio enthusiasts**
- **Available from many sources**
- **Recent military activity in Europe has made access to tubes made in Russia difficult**

Status of the Tube Supply

- **New Sensor is the owner of EHX, Mullard, Tung-Sol, Genalex Gold Lion, Sovtek & Svetlana. However, Russian tubes can no longer be exported.**
- **Shuguang just returned after a 5+ year hiatus due to a fire - questionable and variable quality**
- **Psvane is a spin off of Shuguang. Psvane & Linlai are the premier Chinese tube brands and their quality is excellent.**
- **JJ is an independent manufacturer in the Slovak republic – successor to Tesla**
- **Many eyes on the new WECo for new additions to their product line**

A Tube Worth Your Attention

- **The New (2017) Tung-Sol KT-120. This is a new tube design from the Russian tube plant in Saratov, Russia**
- **Plug in for KT-88 with minor rebiasing**
- **A plug for Viva Tubes, Easthampton, MA.**

Thanks for your Attention

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