History of Vacuum Tube Manufacturing in the US From WWII to the End

Destruction of the US Consumer Electronics Industry

Paul Hart
Radio Activity
June 3, 2022

In the Beginning
Bell Labs/AT&TCo Perspective (1984)

- Patent situation already complex before WWI
- Many new patents developed and shared during the war
- At the end of the war, chaos in licensing and use of myriad patents from multiple holders
- Some remedy needed if the art was to be reduced to practice
- Remedy was to develop a patent pool
- At the request of the US Government, GE and AT&TCo entered into cross licensing agreement effective July 1, 1920
- Westinghouse and RCA were added; RCA "..had taken over the assets of the Marconi Company in the United States".
- AT&T (through WECo) would manufacture equipment for telecommunications
- GE and Westinghouse manufacture equipment sold by RCA
- Purpose: Free radio development from disastrous litigation – thus assure the public of access to best technical methods

The Patent Scheme Matures and is Exploited

- **RCA ruthlessly exploited the patent pool. License fee was 7.5% of the sale price of a radio + cabinets!**
- **After WWII, Zenith President Eugene McDonald stopped royalty payments on radio tubes, filed suit charging RCA and others with conspiracy**
- **After a worldwide series of comlex actions, RCA settled with Zenith in September 1957.**
- **In 1958, RCA pleaded no contest to anti-trust violation**
- **Hazeltine had its own licensing program – they threatened Zenith – courts dismissed that suit**
- **Zenith proceeded to market color TV sets, initially with better success than RCA**
- **Sarnoff was furious, lost estimated $35M per year**

Is this why Zenith bought Rauland?

Clearly a 6BX7GT made by GE, passed to RCA, then branded Rauland. RCA printed the box. Rauland was a manufacturer of cathode ray tubes.

Sarnoff's Revenge

- RCA's lucrative patent licensing scheme was facing destruction because of Zenith's successful litigation.
- RCA and others provided technical support and advice on organization of the Japanese electronics industry in return for paying to license the RCA patents.
- Sarnoff established a technical center in Tokyo modeled after the Princeton RCA Laboratories
- Ministry of International Trade and Industry (MITI) organized a consumer electronics industry + financing
- Use of predatory dumping to keep domestic prices high, obtain mass production by dumping below cost overseas.

Destruction of the US Consumer Electronics Industry

- Japanese action initially hardly noticed in the US
- From 1958 to 1965, Japanese reduced the US radio industry to a shambles
- In the 1960s, color TV was exploding. Zenith was leading in production and customer acceptance
- Japan attacked the US color TV market
- US Government refused to protect the US interests.
- In 1978, the Zenith Trans-Oceanic 7000 was the last American-made radio in production
- Ironically, in 1986, RCA was sold to GE
- In 1995, Zenith sold controlling interest to LG electronics
- Philips also acquired many historic US named companies

Condition of US Tube Manufacturing End of WWII

- Total production in 1945 was 139 million compared to 108 million in 1940
- Wartime contracts in steep decline
- Major traditional producers - Arcturus, Ken-Rad/GE, National Union, Hytron, Tung-Sol, Raytheon, Westinghouse, Sylvania and RCA
- Many had built new factories financed by the government, not economical after the war.
- Pent-up needs kept demand high; contract cancellations and pricing pressures required gradual "shake-out" of facilities
- Example - special situation of VT Fuze tubes

Special Case of Western Electric

In 1944:

WECo. Produced 1,540,000 tubes
Subcontracted 1,543,000 tubes
Services ordered 3,395,000 tubes from other manufacturers built to WECo. Designs – e.g., 6AK5

By the end of the 1970s:

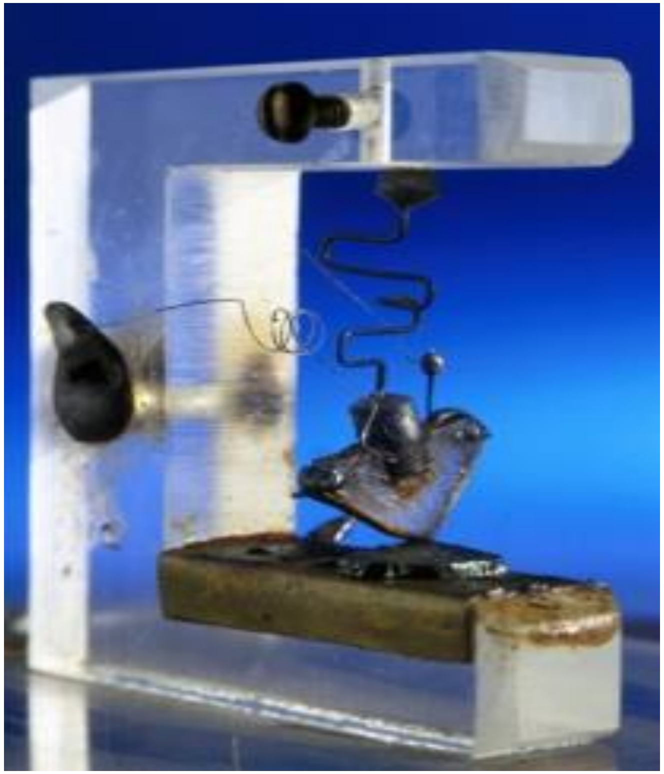
Except for some specialized tubes, development work was minimal
In 1974, Western Electric produced 1,200,000 tubes.
On Dec. 31, 1983, by court order, the Bell System ceased to exist.
Last manufacturing facility in Kansas City closed in 1988
Last tube produced was the "magnificent" 300B audio triode

Invention of the Transistor

- **The transistor was not an accident: AT&T had determined prewar that the evolving telephone system would be untenable with vacuum tubes.**
- **Three fundamental researchers, Bratten, Bardeen and Shockley were brought together to develop a vacuum tube replacement.**
- **Transistor invented in 1947**
- **Announced to the public in 1948**
- **The transistor made phase-out of the vacuum tube inevitable, but not necessarily the demise of the of the US consumer electronics industry**

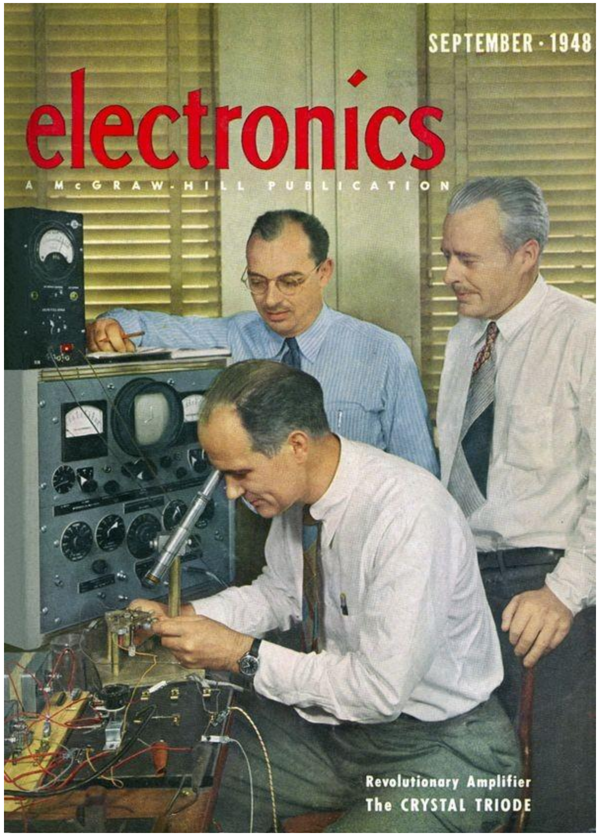
Invention of the Transistor

Replica of the first working transistor, December 24, 1947



W. Shockley, W. H. Brattain and J. Bardeen

Nobel Prize in 1956



Public Announcement
June 30, 1948

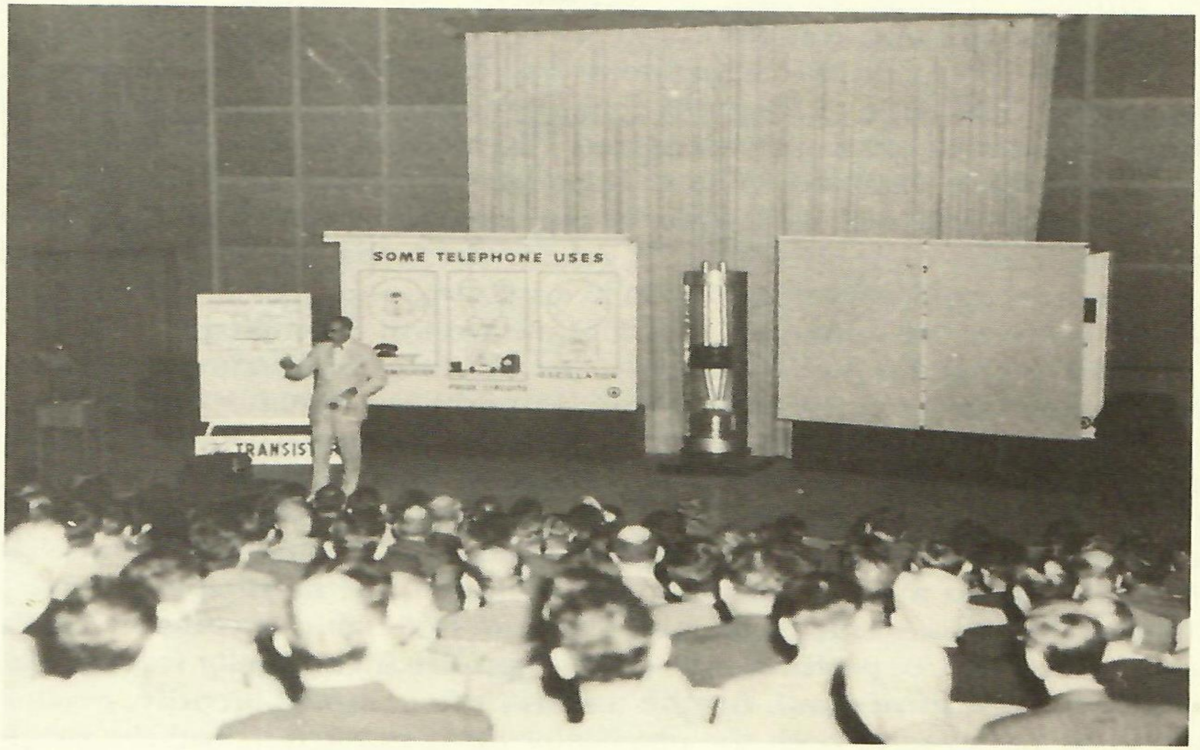
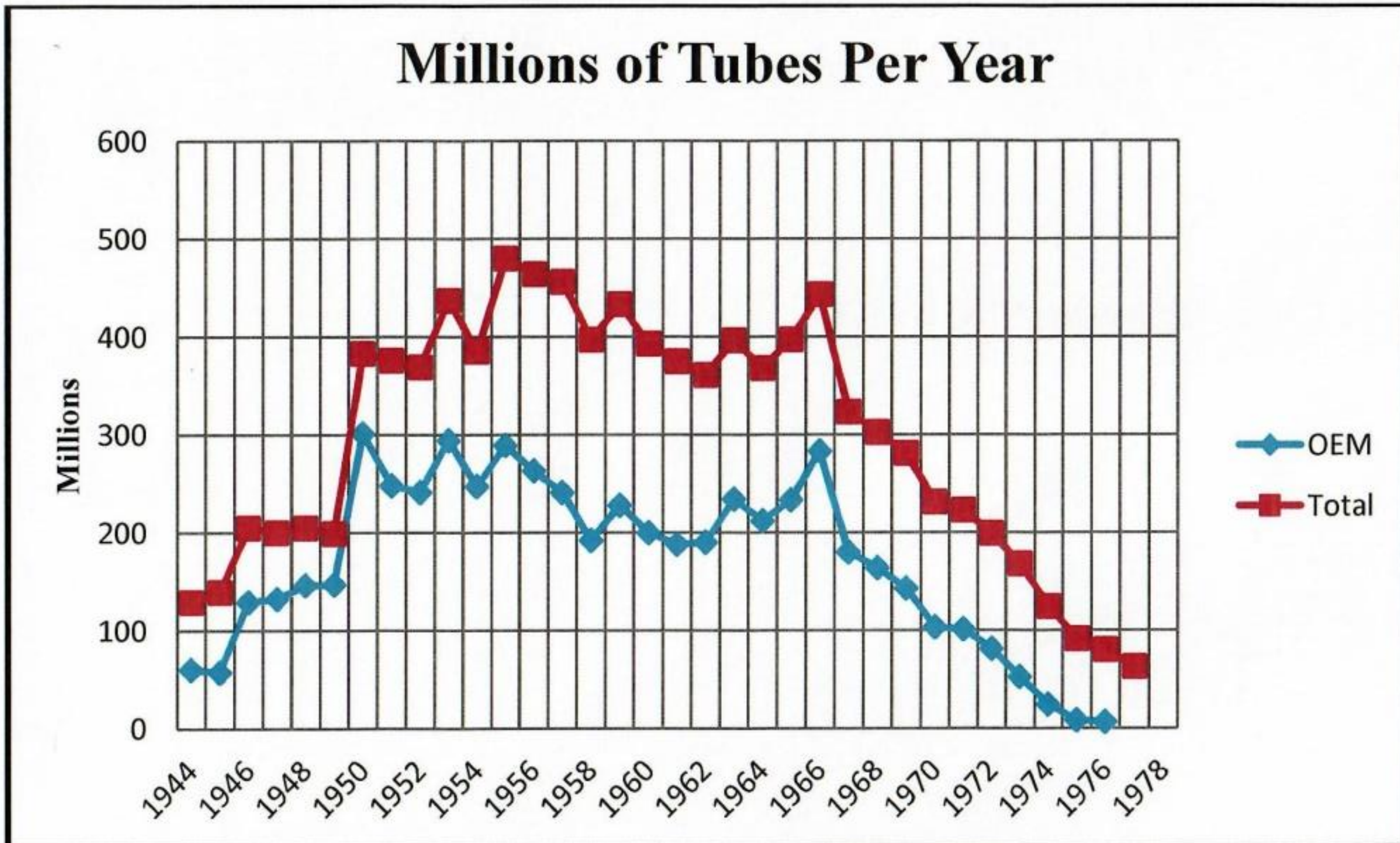


Fig. 1-8. The June 30, 1948 press conference demonstrating the transistor to the public. R. Bown, director of research, addresses the audience in the auditorium of the Bell Laboratories facility on West Street in New York City.

US Vacuum Tube Production
1944 to 1978

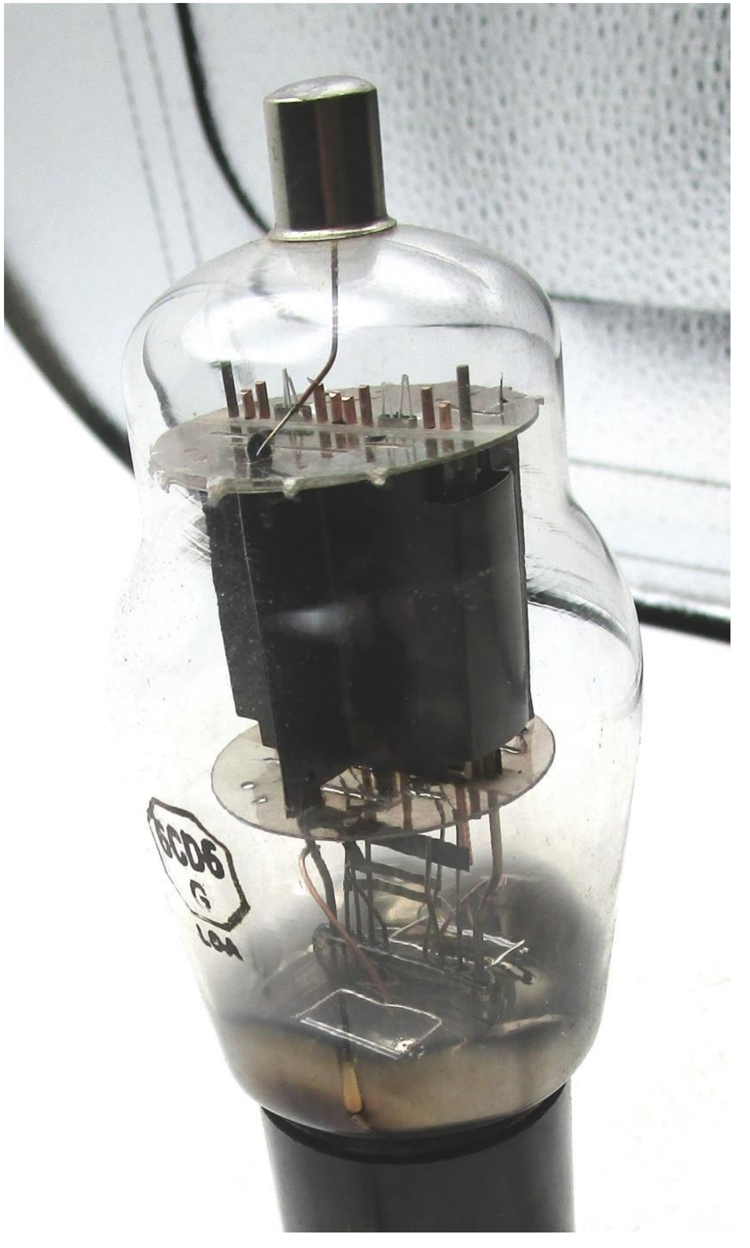


Resumption of Commercial Demand

- **M-R program during the war (1942-1945) provided some tubes to the domestic market**
- **Tube manufacturers first had to satisfy pent-up demand created by wartime shortages**
- **Resumption of consumer and industrial electronics introduction of new tube designs specifically to address the circuit demands of new and evolving TV requirements.**
- **6BG6 in 1946, 6CD6 in Nov. 1949**
- **Current defined filaments with odd voltage ratings for series string operation**
- **In many cases, traditional types were upgraded to increase capabilities – controlled warmup time.**

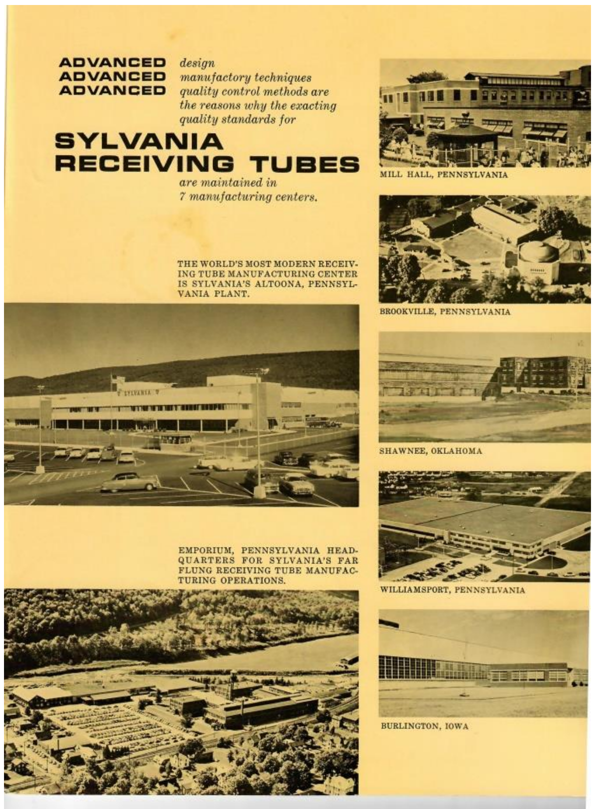
The odd case of the Sylvania 6CD6G

Actually two cage assemblies side by side under a common plate structure. This tube manufactured December 1950 in Altoona. Examples in captivity are dated as late as 1953. The GA was of more traditional construction.



Sylvania Publicity

7 Sylvania Tube Production Locations in 1959



New Design of the 6SN7 November 1954

SYLVANIA NEWS

TECHNICAL SECTION

NOVEMBER 1954 Vol. 21, No. 9

William O. Hamlin, Technical Editor

This information in Sylvania News is furnished without assuming any obligations

Binders With Complete File of Technical Sections: Vol. 1: $1.00—Vol. 2: $1.00—Vol. 3: $1.00—Vol. 4: $1.00

THE SYLVANIA 6SN7GTA IMPROVED DUO-TRIODE

The new Sylvania Type 6SN7GTA should be good news to those who have had plate voltage breakdown troubles and microphonism in equipment using the Type 6SN7GT. A construction comparison between these two types is depicted in the figure. An improved tube was developed without deviating from the 6SN7GT operating characteristics by using improved internal construction and new manufacturing techniques.

The wafer stem construction, having several advantages, was adopted for the new 6SN7GTA. First, the connecting leads are further apart, being in a circle rather than in a straight line; thereby permitting larger peak plate voltages. Also, heat is conducted away faster from the inside of the tube because of the shorter stem leads, thus increasing the allowable plate dissipation and reducing stem electrolysis. These and other features of the Type 6SN7GTA are explained in the accompanying comparison table.

Operation and Replacements

The Type 6SN7GT has been popularly used in television receivers as the vertical sweep oscillator and discharge tube or vertical output amplifier, in addition to a multitude of

(Continued to page 8)

Sylvania Types 6SN7GTA on the right, and 6SN7GT on the left. The shorter, sturdier construction of the 6SN7GTA results in improved performance and longer life. Notice how the wafer stem (glass base) substantially reduces the length of the base leads.

COMPARISON OF THE 6SN7GT TO THE NEW 6SN7GTA

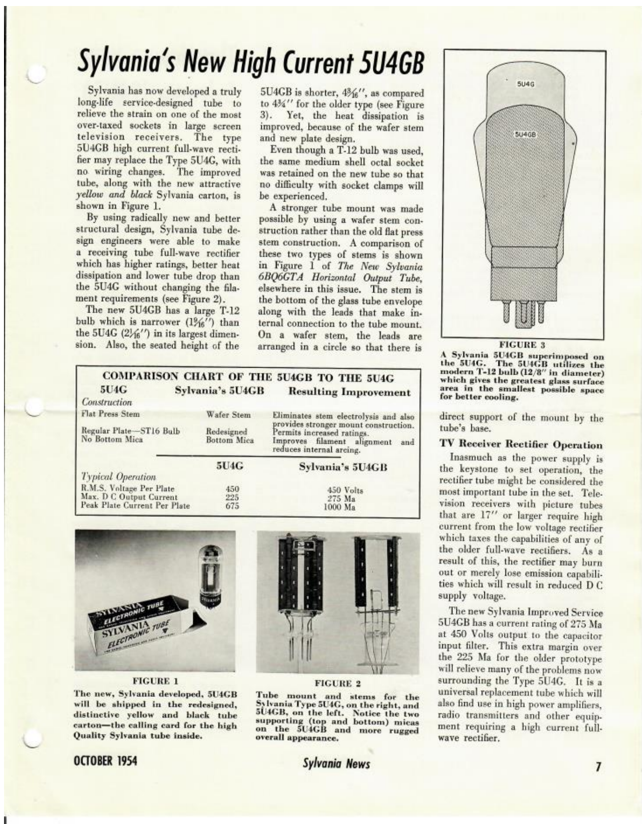
6SN7GT	Sylvania's 6SN7GTA	Resulting Improvement
Construction		
Flat press stem	Wafer stem	Higher peak positive plate voltage. Shorter stem leads, resulting in heat reduction.
Sections oriented in a plane parallel with each other.	Sections oriented at oblique angle with respect to ea. other.	Tends to reduce microphonism. Makes mount stronger, because plates are welded directly to the stem pins.
Plate with wing	Plate with larger and longer wing.	Permits increased plate dissipation.
Rectangular top Mica with teeth.	Oversize round top mica with teeth.	Reduces microphonism.

	6SN7GT	6SN7GTA
Ratings		
Maximum D C Plate Voltage	300 Volts	450 Volts
Maximum Peak Positive Plate Voltage (Abs. Max.)	1200 Volts	1500 Volts
Maximum Plate Dissipation		
Each Plate	3.5 Watts	5.0 Watts
Both Plates	5.0 Watts	7.5 Watts

NOVEMBER 1954 *Sylvania News* 5

More 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 (1⁹⁄₁₆″) than the 5U4G (2¹⁄₁₆″) in its largest dimension. Also, the seated height of the 5U4GB is shorter, 4³⁄₁₆″, as compared to 4¾″ 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.
Regular Plate—ST16 Bulb	Redesigned	Permits increased ratings.
No Bottom Mica	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

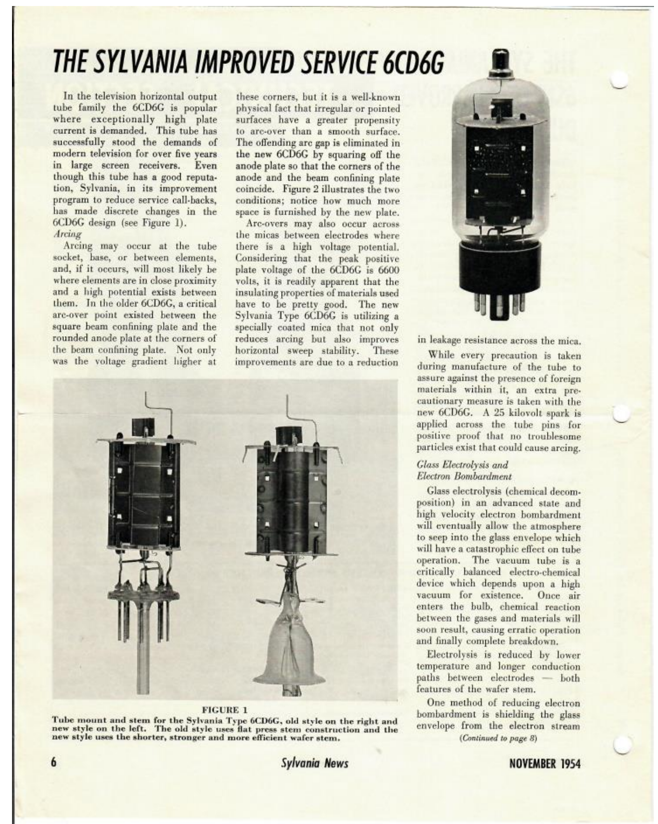
Tube mount and stems for the Sylvania Type 5U4G, on the right, and 5U4GB, on the left. Notice the two supporting (top and bottom) micas on the 5U4GB and more rugged overall appearance.

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.

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

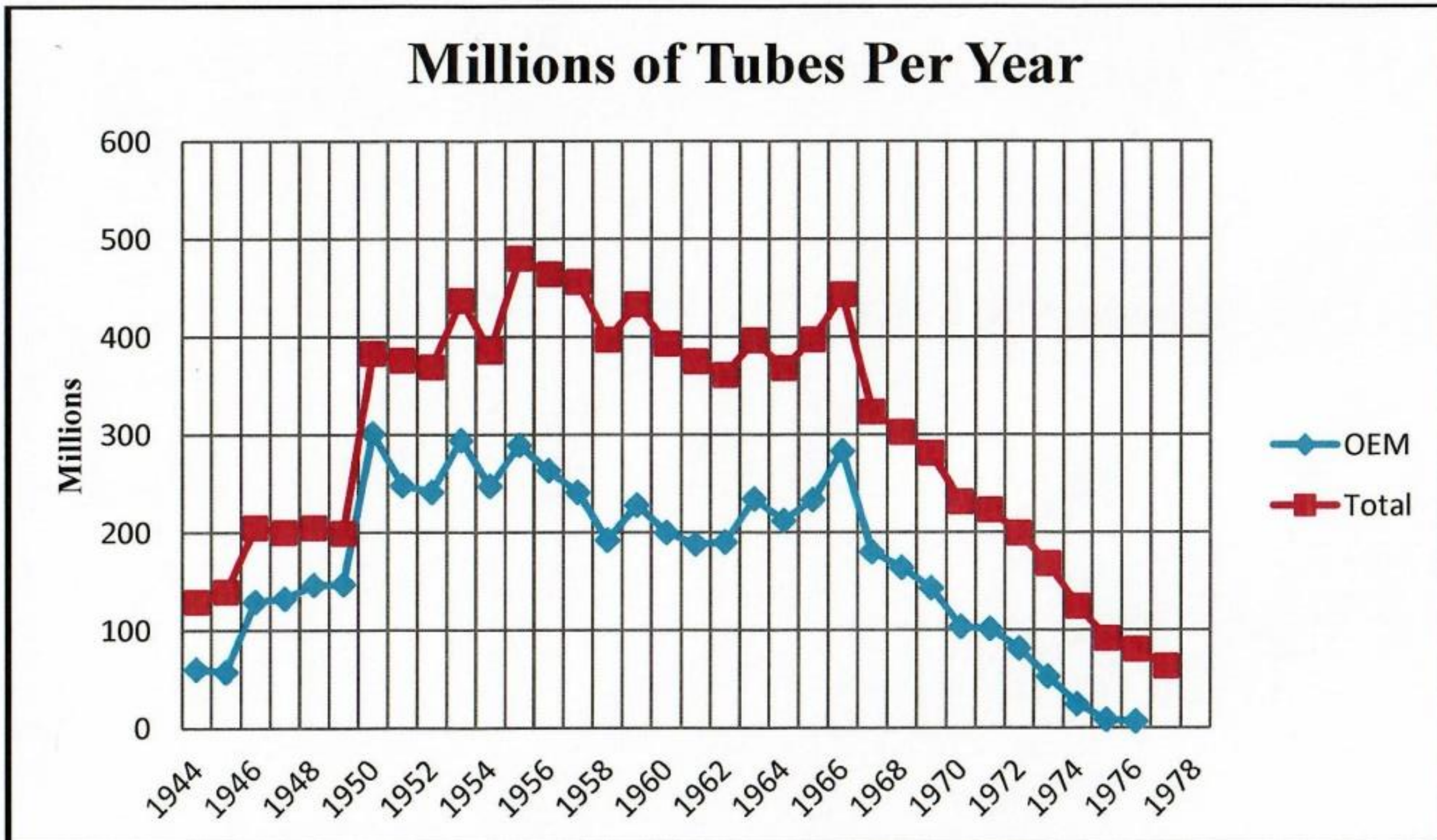
(Continued to page 8)

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.

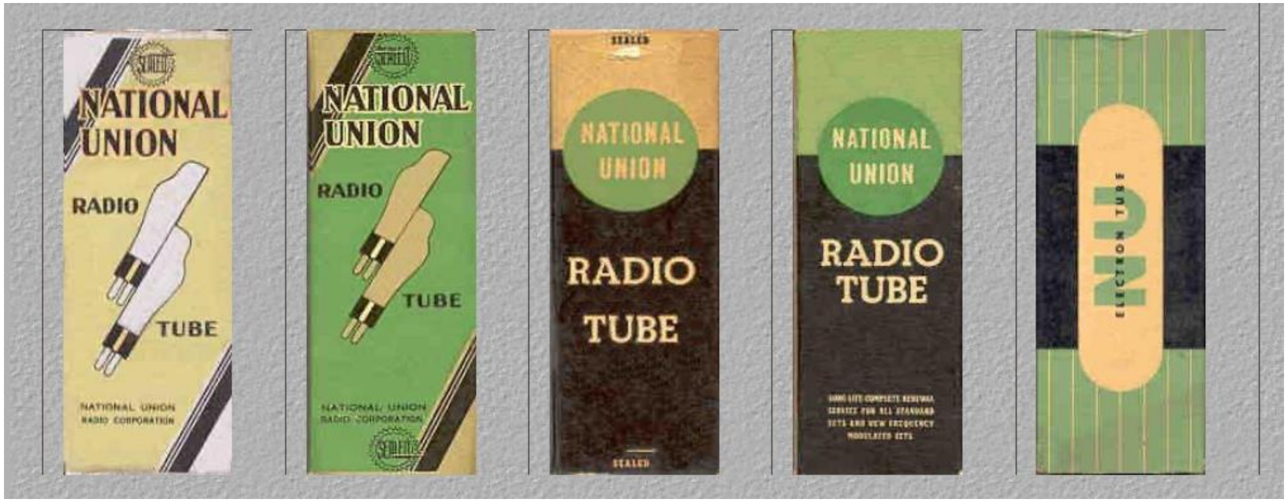
US Vacuum Tube Production 1944 to 1978

Source: Declining Demand, Harrigan, pgs 77-78



National Union
1954?

- National Union was a major tube manufacturer exiting from WWII
- Lansdale, PA tube plant was built during the war as a government lease facility; subsequently purchased by NU
- After the war, converted to receiving tube production
- Lansdale purchased by Philco in 1947
- Last confirmed date on NU tube is 1954

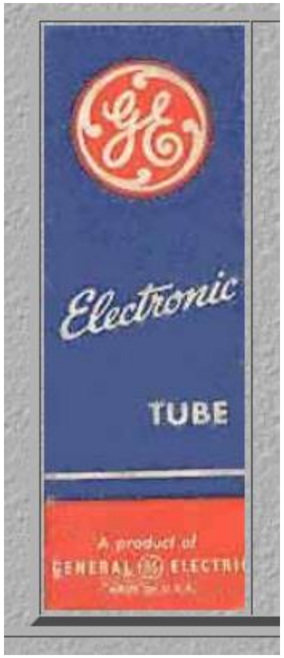


1955 The Highest Production Year

- By 1955, transistors had begun to be adopted where low power and reliability were essential for uses where cost was not a major issue
- Diverse views on when transistors would begin to replace tubes in consumer products.
- By 1966 solid state had not been commercialized as fast as many experts had expected. Exiting and consolidation had begun.

New GE Factory, 1956

- **In 1956, GE built a new 110,000 sq. foot factory on Hartford Road to expand tube manufacturing capacity**
- **In 1970, GE opened a factory in Singapore making miniature tube mounts. Explanation - due to lower cost competition:**
  - **Change from tubes to transistors**
  - **Increase of imported TV sets**
  - **Significant use of imported tubes in the US**



Sylvania Positioning for Long Term Production of Vacuum Tubes

- Altoona was built as a commitment to efficient mass production of large run vacuum tubes
- Emporium facility continued to serve as the engineering center and specialization in short run and unusual designs
- Emporium also produced vacuum tube production equipment used by Sylvania and other vacuum tube manufacturers
- GTE acquired Sylvania in 1959

Sylvania's Commitment 1958 Altoona Plant

Implications: Decision of a set manufacturer to exit tube manufacturing

- Many equipment manufacturers also had tube manufacturing facilities
- Historically provided PBR tubes to repair facilities and distributors
- Smaller manufacturers got most of their tubes from larger producers
- Did not want to damage brand value by discontinuing supply of tubes to their repair facilities and dealers
- RCA had a particular problem

Private Brand Replacement (PBR) Tubes

1961

GE closed Scranton, moved assets to Owensboro KY; closed Anniston, AL. Introduced the Compactron. RCA closed Indianapolis. Sylvania closed Mill Hall, PA and Shawnee, OK.

CBS Exited vacuum tube and television manufacturing.

Philco exited vacuum tube and television manufacturing. Ford bought the Lansdale plant to build car radios.

Raytheon 1963

- **Consolidated receiving tube manufacture in Newton, MA**
- **Shortly thereafter, divested its manufacturing business and sold its equipment in Europe**
- **Contracted with Nippon Electric to provide fast moving replacement tubes branded Raytheon**

In 1966:

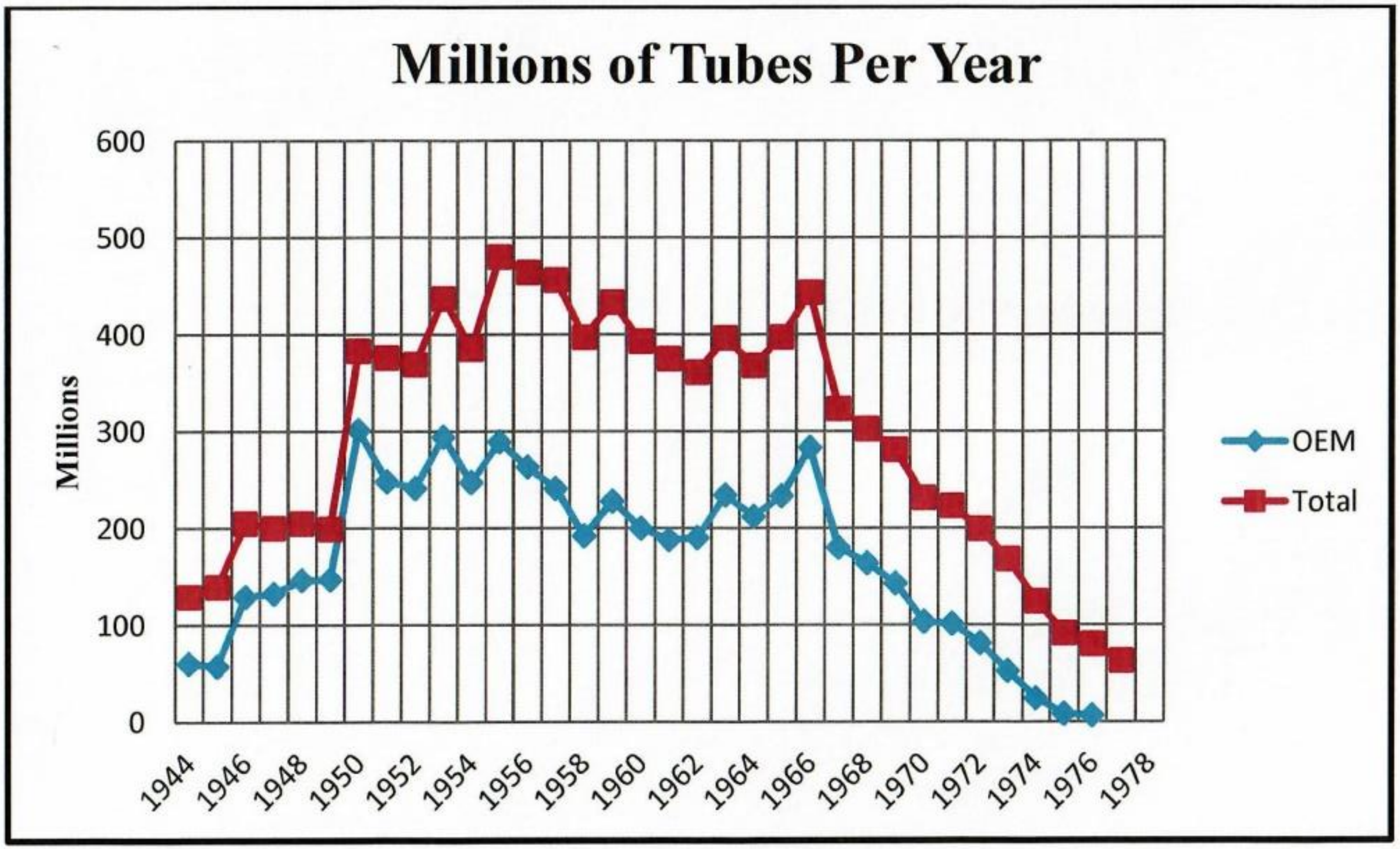
- **Only 4 major manufacturers remained**
  1. **RCA – 34%**
  2. **General Electric – 30%**
  3. **GTE/Sylvania – 30%**
  4. **Westinghouse – 6%**
  5. **Amperex – small/increasing**

- **GE and GTE/Sylvania had continued significant investment in modern mass production facilities**

- **Raytheon, Hytron (CBS), Philco had quit manufacture of tubes. Tung-Sol merged into Wagner Electric. Only Raytheon and Philco continued to merchandise tubes under their own brand.**

Wagner Electric military contract 6550, tube labeled Tung-Sol dated 1975 verified

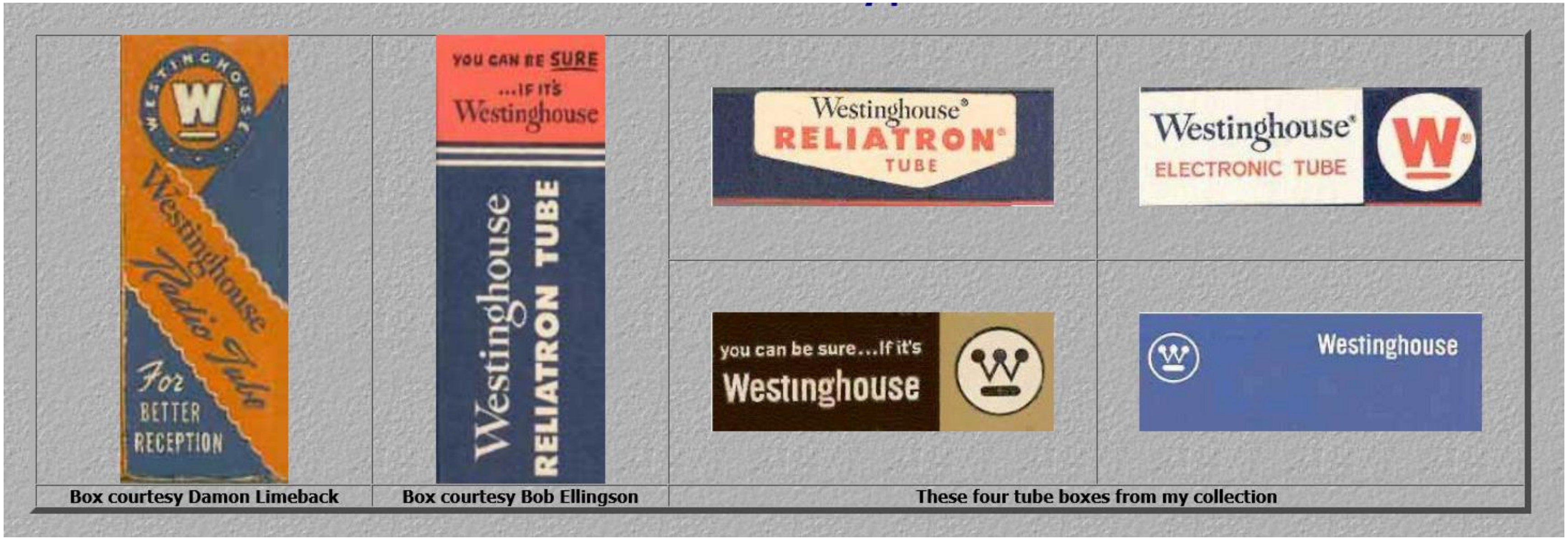
US Vacuum Tube Production
1944 to 1978 (Note 1966 peak)



1967

Majority of radios and phonographs had been converted to solid state.

Westinghouse discontinued manufacture of TV receivers and vacuum tubes but continued to sell tubes from others under its own brand. Taiwan tube plant sold to Union Electric, GTE/Sylvania purchased it in 1975 and subsequently abandoned those assets.



Box courtesy Damon Limeback | Box courtesy Bob Ellingson | These four tube boxes from my collection

1967 - 1969

By 1967, marketing of Japanese receiving tubes was in full force. In 1967, EIA started litigation in the Treasury Department challenging Japanese dumping in the US. Japanese capacity was estimated at 200 million/year. Treasury took no action; dismissed the EIA complaint in 1969.

1969

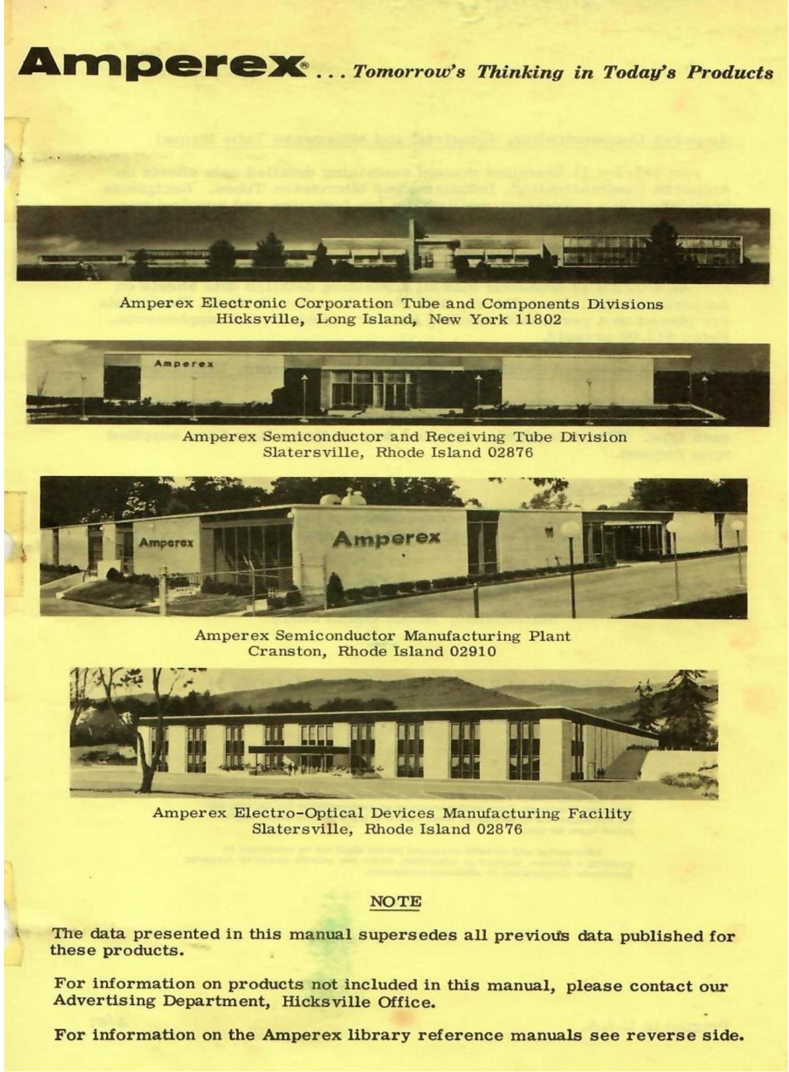
- **Transistors increasingly used in TV receivers. High voltage/high power circuits still used tubes.**
- **Premium value high fidelity tube demand continued**
- **Steady demand for military and industrial tubes**
- **RCA completed shutdown of receiving tube operations in Cincinnati.**
- **GTE/Sylvania closed its Burlington, IA receiving tube plant. Usable tube-making assets were transferred to Altoona.**
- **Majors announced price increases.**

1970 - 1974

- **1970 RCA closed the Woodbridge, NJ and Cowansville, QC receiving tube plants. Only the old Harrison, NJ plant remained operating. The plant had not been upgraded; its operation required extensive hand assembly procedures.**
- **1973 A niche market shortage developed in Japan due to shortages of audio tubes.**
- **1974 The microprocessor was introduced – a dismal year for tube sales. Last hybrid TV receiver sold.**
- **1974 GE closed the Tell City, IN plant which had been a WWII branch factory. Mothballed the Hartford Road plant.**

1975

- Amperex, which had been acquired by Philips in the fifties exited the tube market.
- Continued sales of Philips Dutch tubes under Amperex globe brand
- Illustration to the right, dated 1967 shows four locations manufacturing a variety of devices including semiconductors, electro-optical devices, vacuum tubes and an extensive line of industrial tubes.
- It is likely that the Hicksville plant was closed and other locations continued.



RCA Finally Quits
April, 1976

- The Harrison facility dated back to Edison and was a 24 building complex covering 650,000 square feet. RCA had been considering exit strategies as early as 1971.
- GTE/Sylvania purchased 10% of the tube equipment, the right to produce Nuvistors and 60 unique receiving tube designs.
- The Nuvistor assets were moved to Emporium, PA
- The 60 special type assets were moved to Altoona, PA
- RCA's vacuum tube assets amounted to 3% of company value

Tube Boxes in this table from my collection

Post-RCA Departure

- **1977:**
  - **GE restarted manufacture of metal tubes, previously manufactured by Ken-Rad**
  - **GTE worked the purchased assets into its operations. 90% of its tubes were made in Altoona, specials and short runs in Emporium**
- **1978:**
  - **RCA finally sold off its retained inventory but remained in the tube resale business until at least 1985**
  - **Only Nippon Electric Co (NEC) and Matsushita remained as Japanese importers/sellers**

Absent from the Harrigan Study

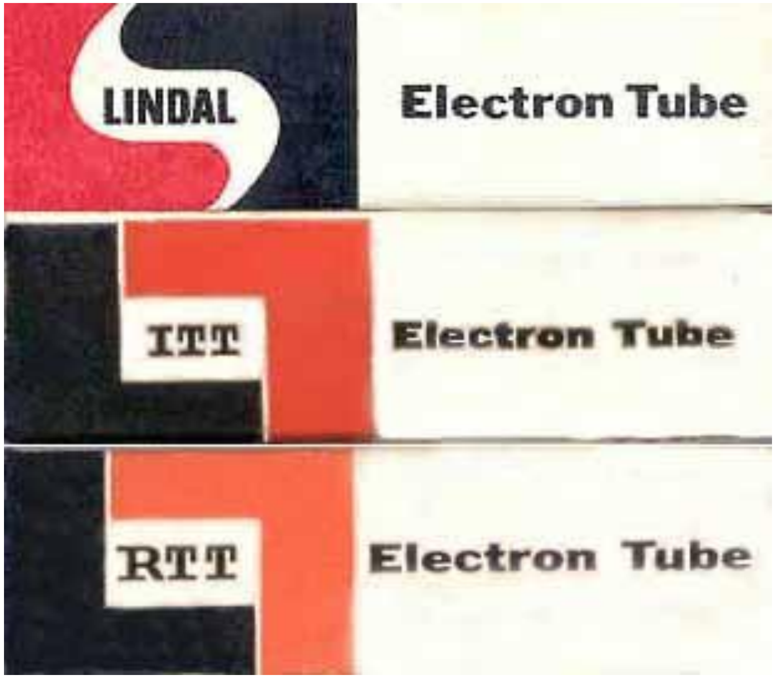
Harrigan presents no data on European imports, which started in the 50s.

Mostly premium audio types from:

- **Mullard/Blackburn England**
- **Philips tubes from Heerland, NL marketed in the US as "Bugle Boy" and world logo under Amperex brand.**
- **Telefunken from Berlin and Ulm factories**
- **Later – Believed to be a Siemens factory owned and operated in East Germany**

Supply Attempts in the Decline

- **Likely sequence of brands in distribution to serve the replacement market**
- **Personal experience is that these were generally good quality domestic or Japanese tubes directed to TV service industry**



The Wild West of Audio Tubes

- Demand for premium audio tubes continued, and provided a golden opportunity for counterfeiters
- An extreme example shown below

1980 - 1988

- **1980 - Philips bought the GTE/Sylvania properties in Williamsport, Emporium and Altoona, PA.**
- **Final tubes produced in 1988, Altoona closed in August.**
- **Delayed use of Philips name on commercial products**
- **Philips also wanted the Electronics Components Group (ECG) based in Williamsport**
- **Exploited ECG as a supplier of electronics repair parts from multiple sources for many years.**

General Electric and MPD

- **GE merged with RCA in 1986.**
  - **A condition was to divest vidicon production at Owensboro. GE decided to sell the entire facility.**
  - **The plant was sold to an investor group which took ownership Jan. 1, 1987.**
  - **New company was Microwave Products Division (MPD)**
- **MPD continued to manufacture some tubes, mainly audio tubes, well into 1993.**
- **Last ceremonial run of the 6550A was on June 17, 1993.**

One of the Last 6550A run
June 17, 1993

The End

Thanks for your Attention

I hope you have enjoyed the presentation.

For a pdf copy of the slides, send an email to PKHartHAVE@gmail.com with
“MAARC last tube”
in the subject line.

Paul Hart
June 3, 2022

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