Acorn Tubes

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Tubes and Radio Applications Up To the Early 1930's

- Tube construction - very much like lightbulbs
- Used 4 to 7 pins (no octals, locktals, or miniature tubes)
- Radio used primarily for long range communications at High Frequency (HF) or lower
- Amateurs restricted to 200 meters (1.5 MHz/Medium Frequency [MF]) until 1924
- Expanded to 80 (3.75 MHz/HF), 40 (7.5 MHz/HF), 20 (15 MHz/HF), and 5 meters (60 MHz/Ultra-high Frequency [UHF])
- Amateurs only UHF band users
- No VHF bands allocated or used

Up until this time, Tubes were constructed very much like lightbulbs
They used 4 to 7 large pins
There were no octals, locktals, or 7 pin miniature tubes
Radio was used primarily for long range communications at High Frequency (HF) or lower
Amateurs were restricted to 200 meters (1.5 MHz/Medium Frequency [MF]) until 1924
Then the allocated bands were expanded to 80 (3.75 MHz/HF), 40 (7.5 MHz/HF), 20 (15 MHz/HF),

and 5 meters (60 MHz/Ultra-high Frequency [UHF])
Amateurs were the only users of the UHF band
There were no VHF bands allocated or used

New Developments

- 1934 – Atlantic Highlands, NJ
  - RCA engineers Irving Wolff and Ernest Linder
  - U.S. Army Signal Corps demonstration
  - Detect boat using transmitter, receiver, audio amplifier, and two antennas
  - Signal Corps history “this may well have been the first successful use in the United States of microwave radar, or of what eventually became microwave radar."

1934 – Atlantic Highlands, NJ

Two RCA engineers, Irving Wolff and Ernest Linder, of RCA’s Camden research staff, demonstrate the detection of a boat using a transmitter, a small receiver, an audio amplifier, and two four-foot dish-shaped antennas to a small group of U.S. Army Signal Corps engineers

In the words of the official Signal Corps history, “this may well have been the first successful use in the United States of microwave radar, or of what eventually became microwave radar."

New Developments - Continued

- The RCA radar work initiated in 1932
- 1933 RCA study determined standard tubes could only operate up to 3 to 5 meters wavelength (mid-VHF range)
- Key early 1930's development goal - develop tubes that would operate below 1 meter (above 300 MHz/UHF)
- Needed to support point-to-point (microwave) communications, television, and radar

The RCA radar work had initiated in 1932
An RCA study in 1933 determined that standard tubes could only operate up to 3 to 5 meters wavelength (about midway into today's VHF range)
Few tube development goals of the early 1930's were more important than the development tubes that would operate below 1 meter in wavelength (above 300 MHz/UHF)
These frequencies were needed to support point-to-point (microwave) communications, television, and radar

The Acorn Tube is Born

- Direct relationship between wavelength, tube size, and element spacing
- Conventional tubes too large in comparison to operational wavelength
- 1933 - Browder J. Thompson and George M. Rose, Jr., RCA Radiotron research staff developed a breakthrough
- New tube of conventional grid type
- Three-fold reduction in dimensions and three-fold operating efficiency increase
- Oscillating wavelength down to 30 centimeters (UHF)
- Measuring only 3/4-inch - Resembled acorns

There is a direct relationship between wavelength, the size of the tube, and the spacing of its elements

The chief limitations of conventional tubes lay in the fact that the size of the tube became too large in comparison to the wavelength at which it operated

In 1933, Browder J. Thompson and George M. Rose, Jr., colleagues on the RCA Radiotron research staff, developed a breakthrough—a new tube of the conventional grid type, with a three-fold reduction in all dimensions (and a three-fold increase in operating efficiency)

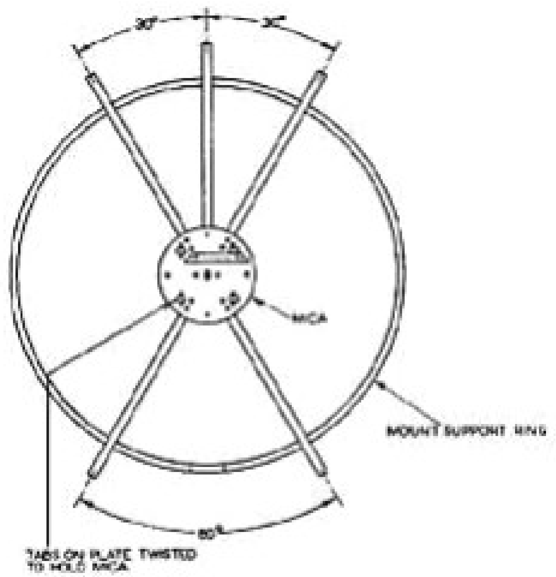
These tubes oscillated at wavelengths down to 30 centimeters, well within today's UHF range

Formed of two glass hemispheres placed together with the elements mounted within, and measuring only 3/4-inch in their largest dimension, the tiny experimental tubes resembled acorns

The First Acorn Tubes

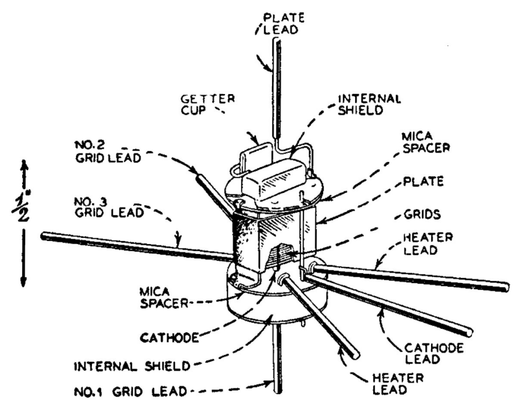
- Issues with production overcome by engineering development
- Sold under "RCA - De Forest" brand - amateur-market, transmitting tubes and CRTs
- First offering 955 triode - March 1935
- Small all-glass tube, short low inductance leads, fast electron transit time, low interelectrode capacitance,
- VHF-UHF applications operating up to 500 MHz
- Followed later in 1935 by 954 sharp-cutoff pentode
- 1936 – 956 released (954 with remote-cutoff)
- 6.3-volt heater-type designs with the pentodes having top and bottom pins for grid and plate

Commercial production at first presented major problems, which was overcome by intensive and ingenious engineering development
Initially these tubes were sold under the "RCA - De Forest" brand which was then used for amateur-market transmitting tubes and CRTs
The first offering in March 1935 was the 955 triode
This small all-glass tube, with its short, low inductance leads, fast electron transit time, and low interelectrode capacitance, was an important advance in tubes for VHF-UHF applications
Operating up to about 500 MHz, Acorn Tubes initiated an era of receiving tube development leading to continuing further advance in shorter wavelength operations
Later in 1935 RCA released the 954 sharp-cutoff pentode
The 956, a 954 with new grid to give remote-cutoff action, arrived in 1936
These were 6.3-volt heater-type designs, with the pentodes having top and bottom pins for the grid and plate

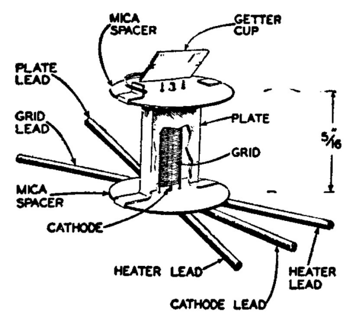


Acorn Manufacturing – specially treated Dumet rod
contact pins temporarily welded to support ring

The first step in Manufacturing Acorn tubes was to temporarily welded the specially treated Dumet rod contact pins to a metal support ring.
The special treating of the rods was to allow them have the same coefficient of thermal expansion as the glass, allowing for a good bond

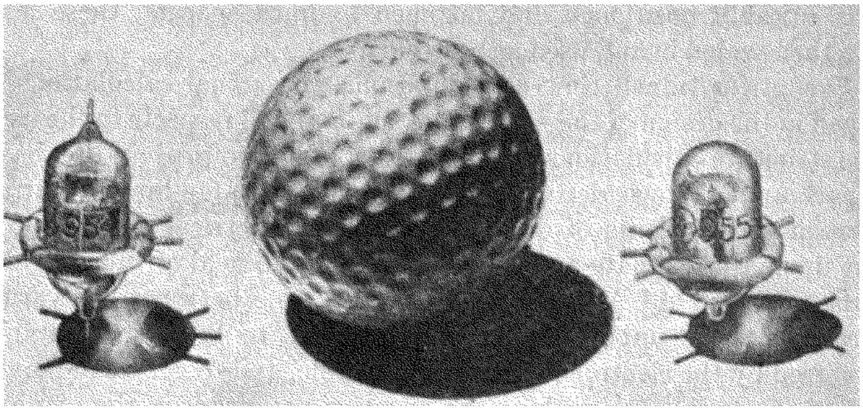


954 pentode



955 triode

Here we see the internal structure of the 954 pentode and the 955 triode



Early 954 pentode and 955 triode - domed tops

The early 954 pentode and 955 triode had domed tops
Here they are shown in comparison to a golf ball

954 pentode 955 triode

Military (JAN) tubes had flat tops

Later military (JAN) acorn tubes had flat tops

Later Acorn Tubes

- 957 receiving triode, 958 transmitting triode, and 959 remote-cutoff pentode followed - 1938
  - 1.25-volt directly heated filaments for VHF/UHF mobile applications
- 1937 - Canadian Westinghouse No. 10 diode (CW10 or 6048)
- WW II military equipment UHF detectors (low signal level rectifiers)
  - 9004 diode with resonant frequency of 850 MHz
  - 9005 diode with a 3.6-volt heater – resonant frequency of 1,500 MHz

The 957 receiving triode, 958 transmitting triode with dual paralleled filaments for increased emission, and the 959 remote-cutoff pentode followed in 1938 with 1.25-volt directly heated filaments for battery-powered use making VHF/UHF mobile applications possible

The 1937 type 953 prototype (R6048), a diode with a plate pin on the bulb top, never went to production, but the Canadian Westinghouse No. 10 (CW10 or 6048) was essentially a 953 with a different getter

Two more WW II military equipment UHF detectors (that is rectifiers of low level signals) were added to the acorn line

> The 9004 was basically a 953 diode without a separate plate pin and a resonant frequency of 850 MHz
>
> The 9005 had a remarkably tiny mount, placed sidewise among the pins, and a 3.6-volt heater. The mount was moved to the usual vertical position in '50s production. It had a resonant frequency of 1,500 MHz.

Later Acorn Tubes - Cont

- 1942 - 958A (958 with tighter emission controls)
- WWII triodes
  - 6F4 - dual grid and plate pins (seven in all) for lower inductance, oscillate up to 1200 MHz
  - 6L4 - 6F4 with lower capacitance and higher amplification
- 1650 - 955 with modified heater and cathode to prevent interelectrode leakage
- 5731 – modified 955 for use in Signal Corps balloon-borne radiosondes

In 1942 the 958 received tighter controls on emission and became the 958A
The line was further expanded during the war to include the 6F4 and 6L4 triodes.

> The 6F4 had dual grid and plate pins (seven in all) for lower inductance and was able to oscillate up to 1200 MHz
>
> The 6L4 was a 6F4 with lower capacitances and higher amplification factor

RCA also produced the 1650, a 955 with modified heater and cathode to prevent interelectrode leakage for use in the Boonton Radio VHF Q-meter
After the war RCA briefly offered the 5731 - a 955 selected for use in Signal Corps balloon-borne radiosondes

Typical Acorn Tube Installation

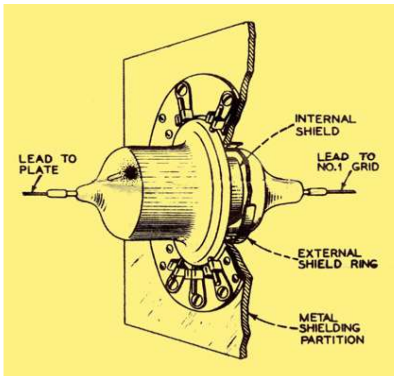


Plate circuit isolated from the No. 1 control grid by internal and external shielding. Top and bottom pins used clip-on connectors.

In a typical acorn tube installation, the Plate circuit is isolated from the No. 1 control grid by internal and external shielding. The top and bottom pins used clip-on connectors.

U. S. Manufacturers

- Developed by RCA, Acorn Tubes were also manufactured by other companies to support the war effort
- Joint Army-Navy (JAN) designations
  - GE (JAN-CG or JG)
  - Hytron (JAN-CHY or JHY)
  - Raytheon (JAN-CRP or JRP)
  - RCA (JAN-CRC or JRC)
  - Sonotone (JAN-COZ or JOZ)
  - Tung-Sol (JAN-CTL or JTL)
  - Westinghouse (JAN-CWL or JWL)

Other Manufacturers

- Mullard - AP4 pentode 'for operation as detector or HF amplifier at ultra high frequencies' (1937) and AT4 triode
- Marconi - ZA1 and ZA2
- MOV - HA1, ZA1, HA2, and ZA2
- Mazda - A40 and A41
- Philips/Valvo - 4671, 4672, 4674, 4675, and 4676
- Philips - D1F, D2F, D3F, and E3F
  - Above had 4V 250 mA heaters and different pin spacing (90 vs 60 degrees)
  - Later switched to match U.S. equivalents
- Lorenz - DSxxx series used in German military equipment during the war
- Hitachi - 95x-types (under pre-war license) for Japan, designated "UN-95x"
- USSR (Czech Republic) - 954, 955, and 956 tubes after WWII
- RTL - France

Mullard released its own acorn designs: the AP4 pentode 'for operation as detector or HF amplifier at ultra high frequencies' launched in 1937, and a triode, the AT4.
Marconi produced two Acorn Tubes, the ZA1 and ZA2
MOV produced the HA1, ZA1, HA2, and ZA2
Mazda produced the A40 and A41
Philips/Valvo manufactured the 4671, 4672, 4674, 4675, and 4676
Philips manufactured the D1F, D2F, D3F, and E3F
The above Acorn Tubes had 4 V, 250 mA heaters and different radial pin spacing (90 vs 60 degrees), which were later switched to match that of their U.S. equivalents
Lorenz in Germany produced a DSxxx series of Acorn Tubes, used in German military equipment during the war
Hitachi made 95x-types (probably under pre-WWII licence) for Japan, designating them "UN-95x"
USSR (Czech Republic) made 954, 955, and 956 tubes after WWII
RTL made Acorn Tubes in France

Table of Acorn Tubes and Equivalents

#	TYPE	FIL V/AMP	MFGR	EQUIVALENTS
954	Pentode	6.3 V 0.15 A	USA	VR95/95A, CV1095, CV1579, ZA2, VT-120, 4672, E1F, KG1, 38954, VR95, VR95A
955	Triode	6.3 V 0.15 A	USA	VR59, CV1059, HA2, ESU111, 10E/11452, VT-121, 4671, 110E/40, E1C, 38955
956	Pentode	6.3 V 0.15 A	USA	CV649, VT-238, 4695, 38956
957	Pentode	1.25 V 0.05 A	USA	CV2700, VT-237
958-A	Triode	1.25 V 0.1 A	USA	VT-212, CV650, 38958
959	Pentode	1.25 V 0.05 A	USA	CV1794, 38959, CV813
1630	Hexode		USA	VT-128, CV2715
1650	Triode	6.3 V 0.15 A	RCA	
4671	Triode	6.3 V 0.15 A	Ph/Val	EC1, 955 and equivalents
4672	Pentode	6.3 V 0.15 A	Ph/Val	E1F, E2F, 954 and equivalents
4674	Diode	6.3 V 0.15 A	Ph/Val	9004
4675	Triode	4.0 V 0.235 A	Ph/Val	A40, Z1, HA1, CV1171, AT4
4676	Pentode	4.0 V 0.235 A	Ph/Val	A41, ZA1, CV1175, AP4, Z2
5731	Triode	6.3 V 0.225 A	GE	
6048	Diode	6.3 V 0.15 A	CW	CW10
9004	Diode	6.3 V 0.15 A	USA	4674, CV666 , CV3675
9005	Diode	3.6 V 0.165 A	RCA	CV667
6F4	Triode	6.3 V 0.225 A	RCA	CV1919, CV2939, CV3639
6L4	Triode	6.3 V 0.225 A	RCA	
A40	Triode	4.0 V 0.25 A	Mazda	HA1, CV1171, 4675
A41	Pentode	4.0 V 0.25 A	Mazda	ZA1, 4676, CV1175, NR54
AP4	Pentode	4.0 V 0.25 A	Mullard	CV1175 ; CV1176, NR54
AT4	Triode	4.0 V 0.25 A	Mullard	NR50, A40, CV1171
CW10	Diode	6.3 V 0.15 A	CW	6048
D1F	Pentode	1.4 V 0.1 A	Philips	D11F
D2F	Pentode	1.4 V 0.24 A	Philips	D12F
D3F	Pentode	1.25 V 0.5 A	Philips	
DS310	Triode	2.0 V 0.78 A	Lorenz	
DS311	Triode	12.6V 0.11 A	Lorenz	
DS320	Triode		Lorenz	
E3F	Pentode	6.3 V 0.2 A	Philips	E13F
HA1	Triode	4.0 V 0.25 A	MOV	A40, CV1171, 4675
HA2	Triode	6.3 V 0.15 A	MOV	CV1059, 955 and equivalents
ZA1	Pentode	4.0 V 0.25 A	MOV	A41, CV1175, 4676, NR54
ZA2	Pentode	6.3 V 0.15 A	MOV	CV1095, 954 and equivalents

NOTE: USA includes GE, Hytron, Ken-Rad, RCA, Raytheon, Sonotone, Tung-Sol and GE and Marconi Canada. Ph/Val is Philips and Valvo. CW is Canadian Westinghouse.

Initial Applications

- National 1-10 and 1-10A (1936-38), NC 510 (1938), RBT (1939), and NUH (1939-41) receivers

National used them in their receivers 1-10 and 1-10A (1936-38), and later the NC 510 (1938), RBT (1939) and NUH (1939-41)

Initial Applications - Cont

- RCA - Beat Frequency Oscillator

RCA used it in a Beat Frequency Oscillator

Initial Applications - Cont

- General Radio - Signal Generators and Vacuum Tube Voltmeters both before, during, and after WWII

General Radio used them in a line of Signal Generators and Vacuum Tube Voltmeters both before, during, and after WWII

Initial Applications - Cont

- Allied Radio Corporation - Don Lee Television Kit - 1937

Most unique was the Allied Radio Corporation Don Lee Television Kit of 1937

Initial Applications - Cont

- Hallicrafters - S-27 (1940–43), S-36 (1942–46), and S-37 (1945–48) receivers

Hallicrafters used them in the S-27 (1940–43), S-36 (1942–46), and S-37 (1945–48) receivers

Initial Applications - Cont

- Hallicrafter – U.S. Navy - based on the S-27, 36, and 37 and the Army R-44/ARR-5 - Also saw action in WWII as search intercept and receivers

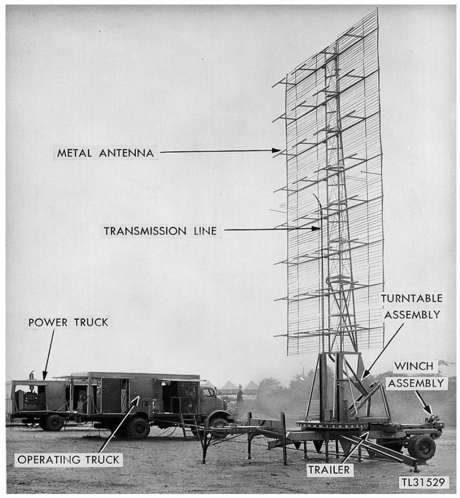
Hallicrafter receivers (Navy - based on the S-27, 36, and 37 and the Army R-44/ARR-5) also saw action in WWII as search intercept and receivers

Use in WWII

- Radar Receivers
  - ASB-4, -5
  - BC-404 (SCR-270)
  - BC-406 (SCR-268)
  - BC-618 (SCR-516)
  - BC-701A (SCR-521A)
  - BC-1082 (SCR-602-T1)
  - BC
  - -1121 (SCR-588B)
  - R-36/TPS-2
- IFF transponders
  - ABA / BC-645
- IFF interrogators
  - BC-663 (SCR-533)
  - BC-1068
  - BN, BP
  - RT-48/TPX-1
- Search and intercept receivers
  - BC-787
  - BC-1269
  - R-44/ARR-5
  - R-593/GR
  - RDC
  - TU-57A (SCR-587)
  - TN-17, -18/APR-4
- Radar altimeters
  - BC-688 (SCR-518A)
  - RT-7/APN-1
- Glide-slope receivers
  - R-15, -57/ARN-5
- Test sets
  - BC-761 (I-109)
  - I-86 (IE-55)
  - I-161 (IE-21)
  - TS-24/ARR-1
  - TS-54/AP
- Miscellaneous
  - BC-655 target transmitter
  - BC-790 (RC-110) radar trainer
  - BC-800A (SCR-729) radar beacon
  - BC-1212 (SCR-549) TV-guided-bomb transmitter
  - I-237 TV-guided-bomb test set
  - R-1/ARR-1 (ZB) homing adapter
  - R-17A/FMQ-1 radiosonde receiver
  - RT-1/APN-2 radar-beacon interrogator
  - RT-3A/ARN-1 navigation aid
  - TBS shipboard receiver
  - TBY backpack transceiver

WWII Use

- Most notably, Acorn Tubes were used in the BC-404 (SCR-270), the Pearl Harbor Radar



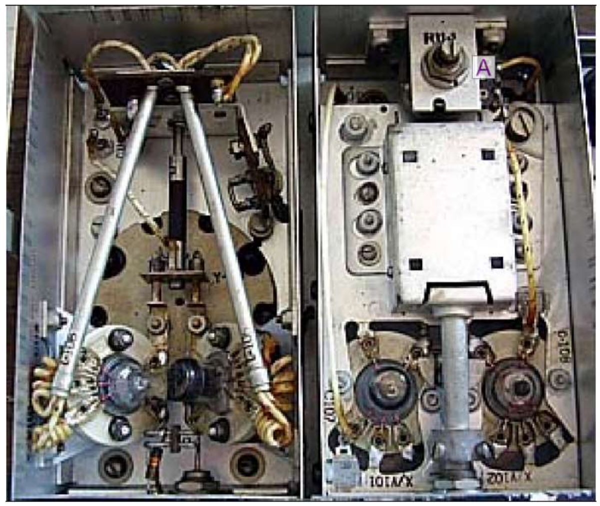
VT-128 – 1630 Tube

Introduced in 1939 by RCA, it was anOrbital-beam hexode electron-multiplier VHF amplifier (secondary emission).
The 1630 orbital-beam hexode was used in early SCR-270 radar sets at 106 MHz as an electron multiplier preamplifier. Due to noise and reliability issues and short working life of about 50 hours only, it was eventually replaced by a module using 6J4 triodes.
The 1630 was also used in Grote Reber's pre-war radio telescopes at 480 MHz, with a 4 stage amplifier providing 100 db of gain.
Actually the gain chain is formed by a tetrode, with an additional focusing electrode, and by a secondary emission amplifier. Electrons come off the cathode, pass through the control and the screen grids and then are accelerated in two curves inside a round beam forming electrode. The two beams, moving in opposite directions, impinge a V-shaped dynode, whose coated surfaces emit several electrons for each hit. These "new" electrons move toward the collecting anode that algebraically sums the electrons resulting from the two beams. As result the signal, common to beams from both directions, is enhanced while random noise is attenuated.

The dynode material "poisoned" the cathode of the 1630, causing the cathode's emission to decrease considerably. This cathode "poisoning" was a problem in all secondary-emission.

WWII Use - cont

- Also used in the FM Radio Altimeter RT-7/APN-1



Problems with Acorn Tubes

- Installing the tube produced side force stresses that could damage the glass seal

- Advances in 7 pin miniature tubes caused the military to drop the use of Acorn Tubes for new designs in 1941

Acorn Follow-on Tubes

- With the development of the seven pin miniature tubes, the 954 and 955 were repackaged

Unique Post WWII Acorn Applications

- Acorns were used extensively in low cost Grid Dip Oscillators

Unique Post WWII Acorn Applications

- They were also used in the Micro-Vox Wireless Mic

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