The Vacuum Tube

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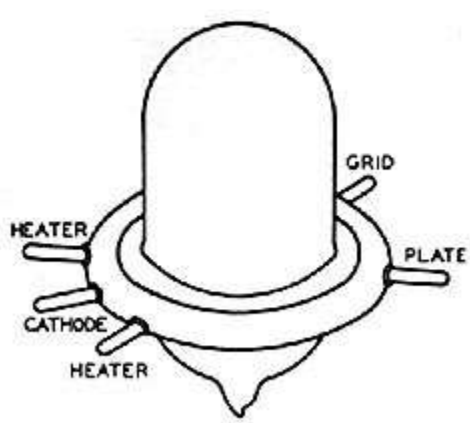
The Acorn Tube

Innovations in tube technology were often important at the time of introduction but faded into disuse after a few years. A vivid example of this effect is RCA's "acorn" tube design, which greatly eased the problem of building equipment for VHF and low-UHF frequencies during the late '30s and early '40s.

This unique design attacked the traditional limitations of tubes at high frequencies by shrinking the dimensions of the elements, adopting a relatively tiny all-glass bulb, and using thick radial element leads of unusually low inductance and capacitance. B. J. Thompson and G. M. Rose of RCA published articles describing an experimental triode and tetrode in 1933-34 [1, 2]. Development continued, yielding a tube in the form that we recognize as the "acorn" [3]. It, and Bell Labs' "doorknob" tube, were the first U. S. physical designs to break free of the "light-bulb" origins of the vacuum tube.



Drawing of original domed version of the 955 triode. Tube measured 1 3/8" from top to bottom.

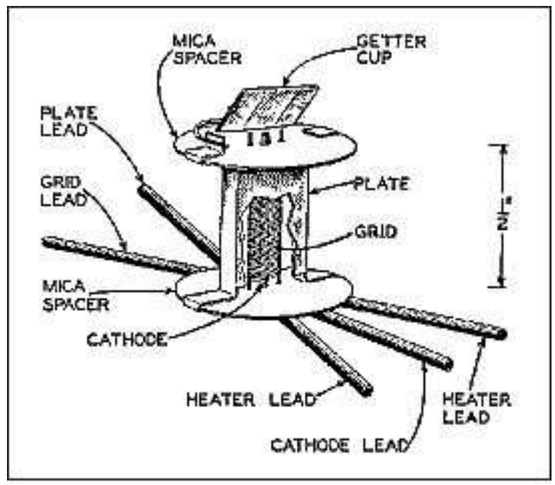
The first commercial tube in the line, and the most important by far, was the 955 triode, announced in March 1935. It was promoted as usable up to 500 MHz. RCA sold it initially under the "RCA-De Forest" brand, which it was then using for amateur-market transmitting tubes and CRTs. The earliest tubes have a rounded dome, more nutlike than the squared-off bulbs of later production. The 955 was accompanied by 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 grid and plate.

They were followed by a group of 1.4-volt types for battery-powered use: the 957 receiving triode, 958 transmitting triode, and 959 remote-cutoff pentode. The 958 had dual paralleled filaments for increased emission [4].

There was also a mysterious 953. NAVSHIPS 900,119 [5], that rich source of half-information on tubes, terms it an "Australian acorn type." Digging through the Dowd-RCA archive reveals a developmental type R6048, tentatively coded "953" at the time, from about 1937. It was a diode with a plate pin on the bulb top. It never reached commercial status in the U. S., but the (Canadian) "Westinghouse No. 10" of WW II was essentially an R6048 with a different getter. The 6048, AKA "CW10," was used in the I-242 power meter for the Canadian-built SCR-602 radar.

Two more diodes were added to the line for WW II military equipment: the 9004 and 9005. The 9004 was basically a 953 without a separate plate pin, for use in radar altimeters. To aid in matching pairs of 9004s, each tube carried a "zone" number, 1 through 6, stamped at the top of the bulb to indicate its relative emission under test conditions. 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.)

In 1942 the 958 received tighter controls on emission and became the 958A. This was in response to a report from the Navy that, in one of their transmitters -- possibly an early model of the TBY -- the tube kept oscillating even after filament power was turned off. Filaments with unusually high emission could keep going, heated only by the plate current.



Internal construction of the 955 triode.

The line was 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. Repackaged later, it yielded the miniature 6AF4 of UHF-TV fame. The 6L4 was a 6F4 with lower capacitances and higher amplification factor. There was to have been a pulse-rated 6Q4 for a Navy project, but it was never introduced. The type designation "6Q4" was reused for a postwar miniature type.

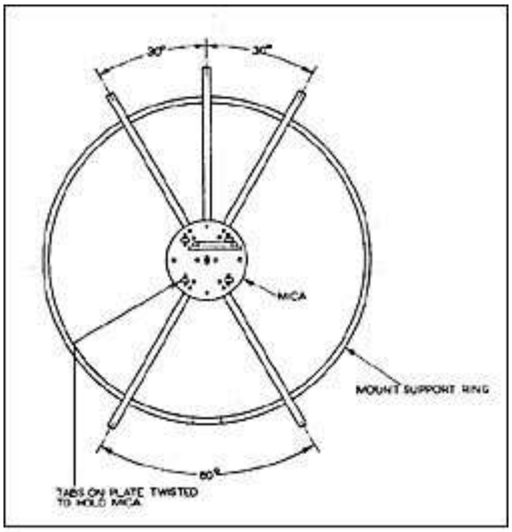
RCA also produced the 1650, a 955 with modified heater and cathode to prevent interelectrode leakage, for use in the Boonton Radio VHF Q-meter. After the war it briefly offered the 5731 (a 955 selected for use in Signal Corps balloon-borne radiosondes).

It's not obvious to the casual observer, but the radial pins on these tubes started out as a group of Dumet rods that were welded to a metal ring. This held the rods rigidly in place as the tube mount was spot-welded to them. After the top and bottom halves of the bulb were sealed to the rods, the rods were cut loose from the ring and tinned.

While these tubes were nominally VHF types, their small size had an appeal of its own. In the '30s, RCA Victor sold a relatively tiny crystal frequency-calibrator using a 955, and a beat-frequency audio oscillator using 954s and 955s. There was at least one construction article on building a broadcast remote console with 955s.

Acorn tubes appeared in the front ends of well known prewar and wartime VHF receivers like the Hallicrafters S-27, S-36, and S-37, and the National 1-10. They served as probe tubes in vacuum-tube voltmeters, and in numerous VHF signal and sweep generators like the Measurements 80, the Ferris 18-series Microvolters, and the General Radio 804. Postwar, they appeared in the Abbott TR-4B two-meter transceiver and the Stewart-Warner "Portaphone" transceiver for the now-forgotten 460-MHz Citizens' Band.

Apart from their "niche" use in civilian equipment, these tubes played an immense role in military gear designed just before and early in WW II. Table 1 shows some U. S. equipment that relied on "acorns" in their RF sections. In most of these sets the tubes ran at 100 to 250 MHz, reasonable frequencies considering their capabilities, but in the BC-645 and ASB they were pushed to 500 MHz. Later ASB models used lighthouse tubes instead, but that's another story.



The Dumet rods that would become contact pins were temporarily welded to metal support ring during construction of tube (see text).

It wasn't just American gear that included acorns: UN-955s made by Hitachi served in the receivers of Japanese VHF radars, and some German radars made by GEMA used Philips and Valvo acorns. The British, although having good VHF-UHF tubes of their own design, made some use of acorn types like the ZA2.

Several U. S. manufacturers made acorn types, particularly 955s, during WW II. As a result, most tubes found today are ex-military, and carry Joint Army-Navy (JAN) designations in either a long form or an abbreviated version ahead of the tube type number. The known makers are: 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).

"GE" 955s are found with either a GE date code, or an RCA code suggesting purchased product. One Tung-Sol 955 inspected was coded with the "MR" symbol, for civilian "maintenance and repair" use!

Many of these tubes are marked in simple white ink, which has been rubbed off over the years. Fortunately, details of construction are quite helpful in sorting acorns out. Table 2 has been developed from an RCA internal aid in the Dowd archive.

The 954, 955, and 956 were repackaged in miniature form as the 9001, 9002, and 9003 respectively. This should be useful to anyone who wants to build a socket adapter to test acorns, and who needs the settings for the tester: just use the test data for bias and plate load from the corresponding 900x tube.

The acorn line served valiantly until better VHF/UHF tubes came on the scene ca. 1941, then abruptly dropped out of new equipment designs. That gave a product life of only about six years. In future articles we will address some of the new contenders.

Table 1 - Military Gear Using Acorns

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

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RT-1/APN-2 radar-beacon interrogator
RT-3A/ARN-1 navigation aid
TBS shipboard receiver
TBY backpack transceiver
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Table 2 - Identifying RCA Acorns

Five radial pins, no pin out top or bottom.
- black plate: 955
- black plate, with white ink dot on bulb above center of
  wide-spaced pins: 1650
- "7" molded in top of bulb: 957
- "8" molded in top of bulb: 958
- tiny nickel plate, in plane of pins or vertical: 9005
- white dot on top of bulb: 5731
- "Zone" 1 to 6 stamped atop bulb: 9004

Five radial pins, plus pin out top.
- Westinghouse No. 10

Five radial pins, plus pins out top and bottom.
- Black plate: 954
- Black plate, with small white ink dot on narrow side of plate: 956
- Nickel plate: 959

Seven radial pins, no pin out top or bottom.
- Black plate: 6F4
- "L" marked atop bulb: 6L4
- "Q" marked atop bulb: 6Q4

References

1. B. J. Thompson and G. M. Rose, Jr., "Vacuum Tubes of Small Dimensions for Use at Extremely High Frequencies," *Proc. IRE*, Dec. 1933, pp. 1707-1721.
2. B. J. Thompson, "Tubes To Fit the Wavelength," *Electronics*, Aug. 1934, pp. 214-215.
3. B. Salzberg, "Design and Use of 'Acorn' Tubes," *Electronics*, Sept. 1934, pp. 282-283, 292.
4. L. G. Pacent, "Acorn Tube Technics," *Electronic Industries*, Sept. 1944.
5. "Cross Index of Electron Tube Types," *NAVSHIPS 900,119*, 4th ed., Bureau of Ships, Navy Dept., April 1946.

Jack A. McCullough, Sr., a cofounder of tube maker Eitel-McCullough Inc., died April 28 at the age of 93. He was born in 1907 in San Francisco, California, received the amateur callsign 6CHE, ca. 1924, and attended college for two years. He joined the tube- and equipment-maker Heintz & Kaufman in January 1930, shortly after H & K hired his future partner Bill Eitel, W6UF.

At H & K, he pumped, sealed and tested transmitting tubes. He and Eitel left H & K in 1934 to form Eimac after the firm's decision not to sell actively to the amateur market. The new company introduced a line of innovative power triodes, starting with the 150T. "Bill and Jack" are shown as co-inventors on most of Eimac's patent portfolio in the early years.

During WW II, the company massively increased production of its power triodes.

Jack McCullough
W6CHE

After reconverting the company to civilian tube production, Eimac expanded into microwave power tubes. Eitel and McCullough sold control of the company to Varian Associates in 1965 but remained as officers into the '70s.

McCullough was an enthusiastic radio amateur, holding the W6CHE callsign for 70+ years. He was active in high- frequency DX work, earth-moon-earth communication, and satellite relaying.

The U. S. Navy gave him its Distinguished Public Service Award in 1950. He was elected as a Fellow of the Institute of Radio Engineers in 1953 for "pioneering contributions to power tube design." He became a Fellow of the Radio Club of America, receiving its Ralph Batcher Award in 1979 and its Sarnoff Citation in 1994. He was an active contributor to Stanford University, where the