Cold cathode rectifiers – the tubes that made Raytheon

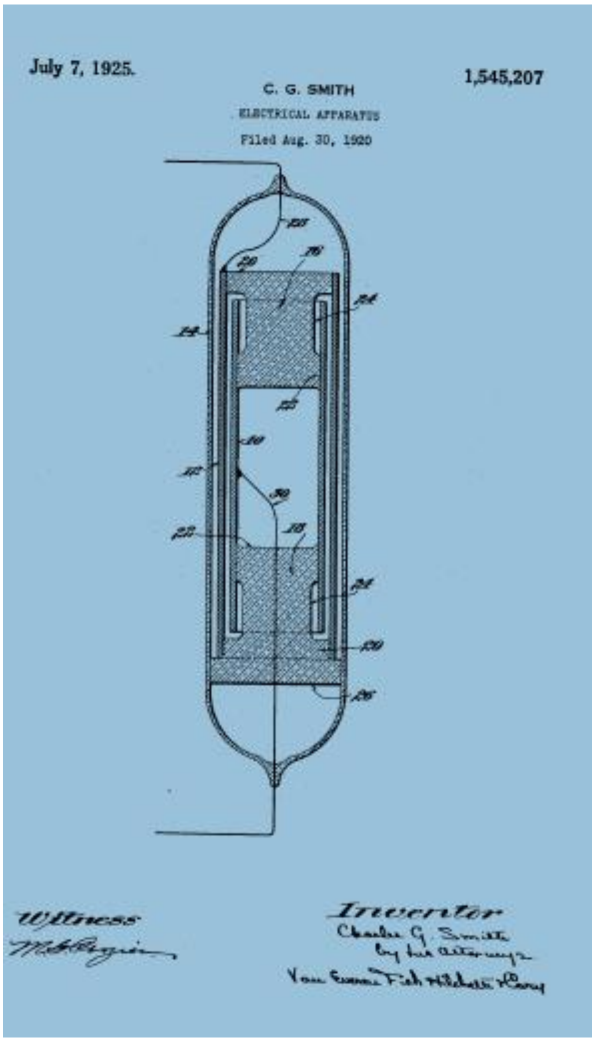
Introduction

The picture below shows samples of Raytheon cold cathode full-wave rectifiers types BH, BA and BH (left to right, pre-1927 to post-1927). Each glass envelope contains helium at low pressure, enclosing pillar-like anodes surmounted by a cap-like cathode.

Rectification occurs because “the current that ionisation causes to flow between two electrodes immersed in low-pressure gas is roughly proportional to the cathode area. Hence if one electrode has a very small area and the other a very large area, a rectifying action takes place”.[i] In the case of the Raytheon rectifiers, the anodes are the tips of wires protruding from the insulated pillars, set very close to and under the much larger cathode cap. Rectification is achieved without a heating filament, though a relatively high voltage is required to start the process, which can produce radio-frequency transients.

The early model BH on the left has a tip on the bulb where the evacuation tube was sealed off during manufacture. It carries a paper label citing 1925 as the date of issue of the US Patent, placing the likely date of its manufacture prior to April 1927, after which “US Patent Law was revised and required that the patent marking ... should consist of the patent number rather than the date of issue”.[ii] The label on the post-1927 model BH on the right cites patent numbers and has a shorter, un-tipped bulb, evacuated through the base. The BA bulb in the centre is un-tipped and is also likely to be of later manufacture.

Early development
Al Spencer, along with the young scientist Charles G. Smith and others, founded the American Radio Company (Amrad) in 1913. Smith's patent filed on 30 August 1920 (granted 7 July 1925) showed how to put into practice the principle of gaseous rectification. His apparatus was an envelope of low-pressure helium enclosing concentric tubular electrodes closely spaced so that "all paths available for discharge through the gas are short and of the order of magnitude of the mean free paths of electrons in the gas".[iii]



Smith's patent was licensed to the associated S-Tube Corporation that produced Amrad S-tube rectifiers from 1922 to 1927.[iv] After initial success, Amrad struggled in the economic recession of the early 1920s. In 1922 Spencer and Smith joined with others, including Laurence Marshall and Vannevar Bush (future head of the Massachusetts Institute of Technology and subsequently scientific advisor to President Roosevelt), to form the American Appliance Company to develop and market a unique refrigeration system of Smith's invention.

Unfortunately, the system proved unworkable and, with half their capital expended and nothing to market, they turned to improving the Amrad S-tube rectifier in order to remain afloat financially. Helped by Spencer's talented brother Percy, Smith refined and developed the S-tube design. As it happened, this coincided with a legal challenge to the company's name, resolved in 1925 by adopting the name "Raytheon". The name is a euphonic neologism meaning "light of gods," alluding to Smith's earlier study of the blue spectra emitted by helium.[v] Thus Raytheon and the cold cathode rectifier emerged together.

Raytheon rectifiers fill a niche

The Raytheon type B rectifier became available in 1925, manufactured by the Champion Lamp Works of Peabody, Massachusetts. It met a demand for battery-free power supplies for the 135V tubes used in the growing domestic radio receiver market. "One of the factors limiting the expansion of the radio business was that all early radios were battery powered ... The constant expense and annoyance of replacing batteries - a frequent occurrence, given the tremendous power requirements of vacuum tubes - created a demand for a more practical power source. Raytheon's rectifier tubes, which converted household AC current to the DC used in radio tubes, provided the answer and helped boost the sales of radio products".[vi]

Raytheon was keen for radio designers and manufacturers to adopt its rectifiers, which were marketed as "battery eliminators" or simply "eliminators".[1] It was a highly competitive market in which the Radio Corporation of America (RCA) held the design patents of many radio receivers. In 1925, in a move that some believed was aimed solely at Raytheon, "RCA raised the standard rectifier operating voltage from 135 to 180 volts…threatening to make the Raytheon B tube obsolete…Raytheon's Percy Spencer quickly responded by re-designing the B tube to comply, resulting in the BH rectifier".[vii] Raytheon's 1928 *Radio Power Bulletin TS-5* showed how to use the BA (350mA) and the BH (125mA) rectifiers to replace the filament, high tension and even the bias battery supplies (A, B and C respectively) in radio receivers.[viii] Raytheon's suggested schematic power supply is shown below.

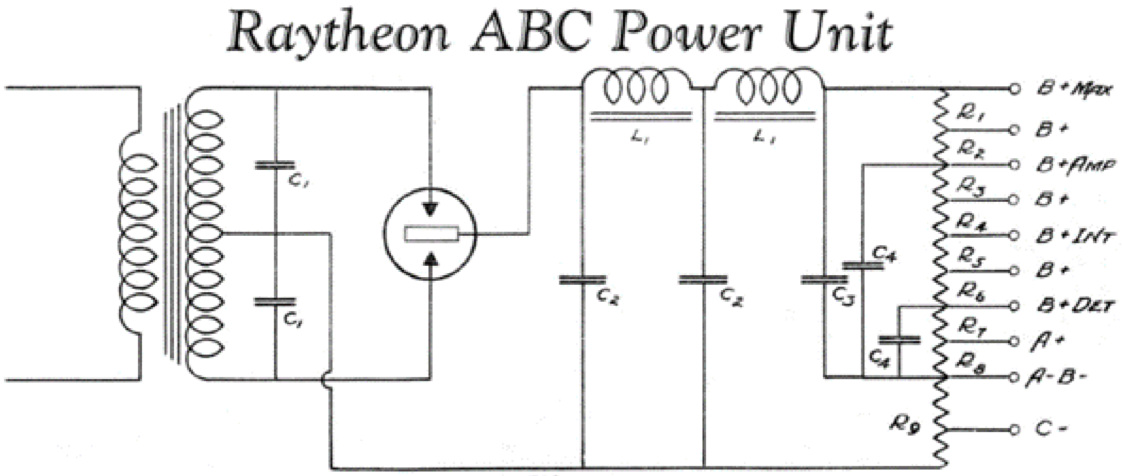


FIG. 3

To heat the filaments of the radio tubes, Raytheon advised arranging them in series for receivers using tube types 201A, 171 and 199, noting that the "Raytheon BH will safely operate a radio receiver with as many as twelve tubes, including a large power tube, providing the proper C-battery grid bias is applied. Or again, the BH will operate as many as eight tubes of 199 type, with their filaments connected in series, supplying A, B and C power, as well as B and C power for a larger power tube".[ix] Raytheon suggested replacing the battery supplies of existing radio receivers (such as the Attwater 30) and its rectifiers were a financial success. "Perfected and introduced to the public in 1925, the tube, known technically as a gaseous rectifier and marketed under the brand name Raytheon, brought in more than $1 million in sales by the end of 1926 and positioned the company as a major contributor to the fast-growing radio tube market for nearly two decades".[x] RCA's response was swift. In 1927, it altered its patent license agreements with radio manufacturers to specify only the recently released type 13 and type 80 filamentary heated rectifier tubes marketed by RCA as *Radiotrons*.[xi]

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[1] A sample of batteries is shown at Appendix 1.

Raytheon expands

Raytheon adapted by expanding its production to include a wide range of radio-receiving tubes, competing with the 100 or more other enterprises already active in the field.[xii] Raytheon enlarged its factory and, from 1 June 1929, the National Carbon Company became the exclusive distributor of Raytheon tubes. National Carbon (later Union Carbide) was the manufacturer of the Eveready battery cells used in radio receivers. Raytheon tubes were packed in boxes branded Eveready Raytheon and printed in the Eveready print style and colours, as shown below.[xiii] This arrangement to market and distribute Eveready Raytheon tubes, including rectifiers and Raytheon's patented "four pillar" receiving tubes, ran for nearly a decade from 1929 into 1938.[xiv]

Raytheon continued to innovate and in 1927, produced a bi-metallic rectifier mainly for tube filament or heater supplies.[xv] It also developed new cold cathode rectifiers for a range of applications, including the metal-shelled 60mA 0Z4 registered in August 1935 and used in automobile radios.[xvi] The 0Z4 continued in use after World War II and on 15 October 1956, Raytheon registered the upgraded 110mA 0Z4A, manufactured well into the 1960s.

Conclusion

Largely unknown today, Raytheon's cold-cathode rectifiers were an interesting, effective and profitable innovation that emerged alongside and competed directly with the filamentary and indirectly heated rectifier tubes that dominated the field until the mid-1960s. Briefly in vogue, cold-cathode rectifiers were arguably the tubes that made (or at least rescued) Raytheon.

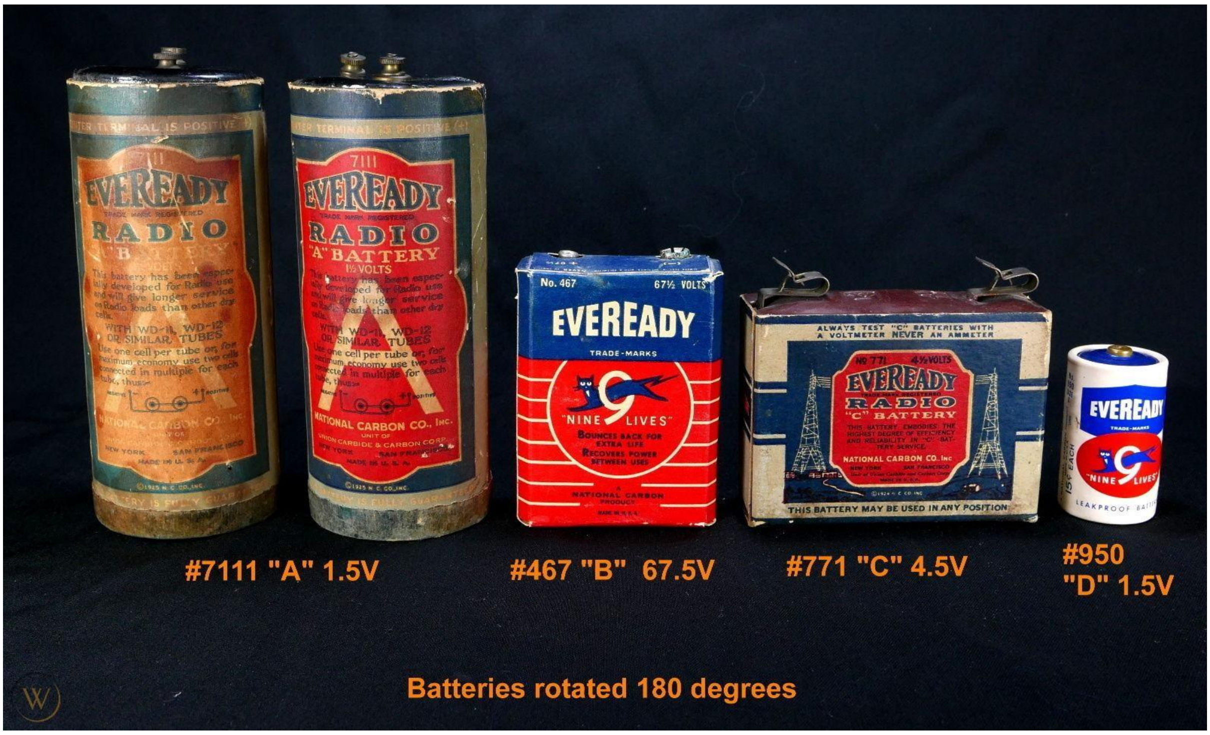
Appendix 1

Early 20th century radio batteries

The two tall 1.5V batteries with thumb-screw terminals date from 1925 and are Eveready 7111 "A" types used to supply tube filaments.

The 67.5 Volt "B" battery (No. #467) with polarised snap connectors was often used in series with other “B” cells to supply high voltage to the tubes anodes.

The 4.5 Volt "C" battery (No.771) fahnstock clip terminals with dates from 1924 and was usually employed to deliver grid bias. Similarly duties were performed by batteries like the 1.5V No. 950 "D" cell shown.



High voltage lower current “B” batteries were usually “dry” carbon-zinc and were replaced when exhausted. Dry cells were also used for the lower voltage, higher current “A” supply of portable receivers, though lead-acid or “wet” cells were common in home receivers. These could be re-charged for a fee by garages using mains-powered General Electric argon-filled Tungar rectifiers, available from 1916 for recharging automobile batteries. See: Sibley, L.A., *Tube Lore II*, 2nd ed., April 2019, p.278.

Endnotes

i Terman, F.E., *Radio Engineers' Handbook*, First Edition, McGraw-Hill, London, 1950, p.591.

ii Tyne, G.F.J., *The Saga of the Vacuum Tube*, first edition, third printing, 1994, p.283.

iii US Patent 1,545,207 of 7 July 1925.

iv See: https://www.radiomuseum.org/tubes/tube_s_amrad.html

v See: https://www.radiomuseum.org/tubes/tube_b_raytheon.htm

vi Earls, A.R. and Edwards, R.E., *Raytheon Company: The First Sixty Years*, Arcadia, 2015, p.14.

vii ibid., p. 17.

viii See Raytheon Manufacturing Company, *Radio Power Bulletin TS-5*, 1928-29 season at: http://www.one-electron.com/Archives/Tube/Raytheon/Raytheon%201928%20Type%20BA%20Bulletin%20TS5.pdf

ix Raytheon Manufacturing Company, *Radio Power Bulletin TS-6*, 1928-29 season, p. 2, at: http://www.one-electron.com/Archives/Tube/Raytheon/Raytheon%201928%20Type%20BH%20Bulletin%20TS6.pdf

x Raytheon Company Historical Background, archived at: https://rjl.home.xs4all.nl/Raytheon_histback.html

xi See Tyne, op. cit., pp. 324 and 325.
At the time, RCA's tubes were made by General Electric and Westinghouse. RCA's first tube manufacturing facility opened in 1930.

xii See: https://www.encyclopedia.com/social-sciences-and-law/economics-business-and-labor/businesses-and-occupations/raytheon-company

xiii See: https://newsm.org/wireless/eveready-raytheon-type-bh-long-life-rectifier-tube/

xiv See: https://www.radiomuseum.org/dsp_hersteller_detail.cfm?Company_id=2383

xv Millen, J., 'The Raytheon "A" Rectifier', *Radio News*, August 1927, p. 128, at: http://www.mcmlv.org/Archive/TubeTheory/Millen%201927%20The%20Raytheon%20A%20Rectifier.pdf John Attwood discusses the early use of copper oxide, selenium and other rectifiers in his article 'Metallic Rectifiers", *Vacuum Tube Valley,* Kittleson, C. (ed), Issue 9, Spring 1998, p. 32.

xvi The octal-based 0Z4 was registered with the Radio Manufacturers' Association on 24 October 1935. The registration documents provided by Raytheon noted that, in common with gas-filled rectifiers, the 0Z4 had a tendency to produce radio frequency noise.