# History of British radar tubes, part 1 - HF gridded tubes

***Foreword: The development of electronic sets and of related vacuum tubes was enormously accelerated in the years just before the Second World War and during the war itself. The most obvious progress regarded radio-localization (radar) systems. In the mid-thirties the upper limit of the radio frequency was slightly higher than 30 MHz while only ten years later, in 1945, radar systems operating at 24 GHz were currently in use. A comparison between the countless systems developed over about ten years by belligerent countries is in fact impossible: yesterday details were strictly secreted, today old systems have been scrapped and in any case it would be impossible to put them back into operation. Nevertheless we have today a reliable way to reconstruct radar history, simply looking at the evolution of radar-specific vacuum tubes designed over the years, mainly for the transmitter. Details of vacuum tubes unveil essential performance of systems in which they were used.***
***This serial overview is mainly focused on British tubes simply because England set most of the standards for modern radar systems, constantly proposing and evaluating new solutions and new components. America played a decisive role in the industrialization and volume production of radar sets, related components and ancillary equipment, but their origin was in England. In that country were devised many VHF / UHF sealed-disc or external anode tubes, the cavity magnetron, the reflex klystron, the magnetron strapping, the silicon mixer diode, the T / R switch and the memory CRT. Even the traveling wave tube, although this only appeared after the end of the war, was devised at Clarendon. Germany probably had a small advantage on UHF triodes at the start of the war but failed to invest in subsequent developments in higher frequency and microwave devices.***

Trying to investigate the history of radiolocation systems in the 1930s, too often are overestimated episodic facts related to simple filing of patents or to experiments intended solely to prove the feasibility of radio-detection. The system that was emerging had to give information about the position of passive obstacles or targets. It could be quite similar to a radio-compass, widely used since the early twenties, with the addition of a self-contained RF transmitter to illuminate targets. The reflection of radio waves by obstacles was well known at the time and this property could be used to 'see' where sight could not reach. Experiments were oriented to systems capable to ‘see’ obstacles in the fog, or even to detect the presence of enemy ships or aircraft and direct artillery fire. The radio signal had to travel twice the distance of the target, from the transmitter to the target and back to the receiver, its attenuation being proportional to the fourth power of the distance itself. Use of high-frequency beams was preferable, since high-gain directional antennas became smaller and lightweight at increasing frequencies. Then the most critical components were power electron tubes capable of generating strong RF pulses at the highest frequencies. These two conditions were antithetical in the 1930s, when most of the power tubes could operate at few megahertz. Feasibility studies on UHF radar systems were conducted almost simultaneously in many countries since the mid-thirties of the last century, using still experimental solutions. The state of the art for high-frequency transmitting tubes in those years is summarized in the article by Kelly and Samuel, appeared in the November 1934 issue of Electrical Engineering (**Bell System Technical Journal 14.1.97**), and in the technical articles given in the RCA book ‘Radio at Ultra-High Frequencies’.

In the mid thirties the upper frequency limit of modern transmitting triodes was somewhere around 100 MHz. In order to reduce transit time and minimize parasitic parameters tube dimensions were small, resulting in severe limits, both in the working voltage and in power dissipation. Transmitting tubes designed for frequencies just above 100 megahertz did not exceed a hundred watts. Higher frequencies could be obtained from triodes operated with positive grid, as proposed by Barkhausen-Kurz. Unfortunately their efficiency was low, around 5%. Furthermore grids were not unable to dissipate heat resulting from impact of electrons. Lindenbland in 1935 wrote of a 6 watt transmitter at 462 MHz, using two **UX-852** power triodes in push-pull. Two **846** water-cooled triodes were used to generate 115 watt at 411 MHz, wasting over than 1 kilowatt only for the heaters. The most efficient source in UHF region was the magnetron. Unfortunately its usefulness as high power source was very poor, due to the low emission of the filamentary tungsten cathodes and even to the poor heath dissipation from the plate segments, usually surrounded by the evacuated glass bulb. In the mid thirties the best performing types were of the split-anode type, operating somewhere between 500 and 700 MHz and rated for CW output power of about 50 watt.

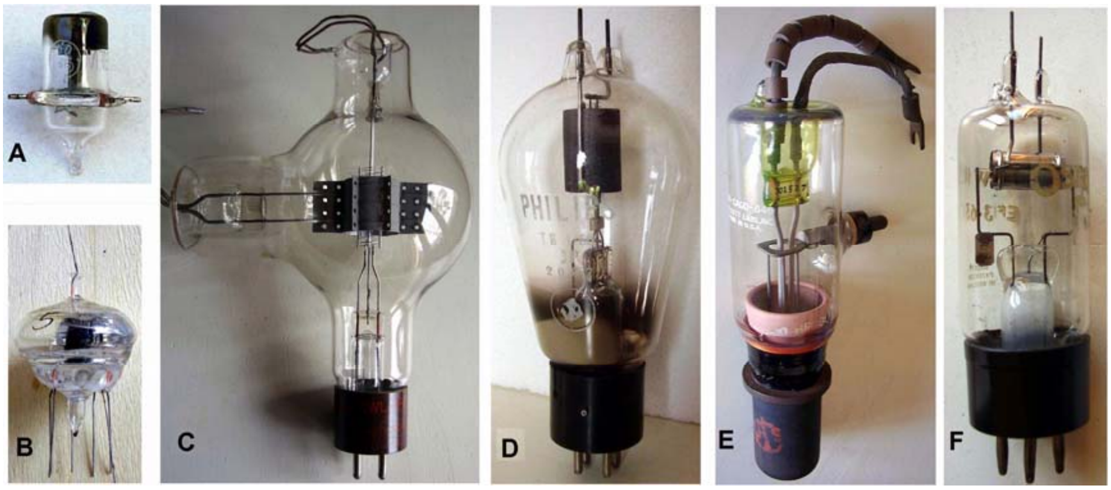


**Fig. 1 - Some of the tubes available around the mid '930s for high frequency operation. A) The 'acorn' 955, introduced by RCA in 1934, was very small, designed to operate as signal amplifier or low-power oscillator up to 600 MHz. B) The Western Electric 384A pentode was another example of small high-frequency receiving tubes, the mushroom family. The family included octal based types, as the 717A. Shortly later the family was rebased to 7-pin, originating universally used types, as the 6AK5. C) The 852, introduced in 1927, used a short and large plate to keep interelectrode capacitances low. D) WE 304A was designed in 1934 to operate up to 350 MHz. The sample in the photo is the Philips equivalent TB1/60, with graphite anode. E) The water-cooled triode 846 was introduced in 1932. Actually it was specified for 50 MHz full ratings but was sometimes used as Barkhausen-Kurz oscillator in the UHF region. F) The MOV CW10 magnetron, designed by E.C.S. Megaw, was advertised from 1936. Its output power was somewhere between 10 and 30 watt, depending upon the wavelength. A similar device was used by Gutton in France, who continued experimenting interdigital magnetrons in the low-power anti-collision system first installed on board of the Normandie liner. The system was intended to sense obstacles straight just ahead of the bow, therefore not requiring high radiated power.**

In November 1934 a paper published in Electrical Engineering and reprinted on the Bell System Technical Journal compared the decreasing size, and consequently the decreasing plate power, of transmitting tubes designed to operate at increasing frequencies.

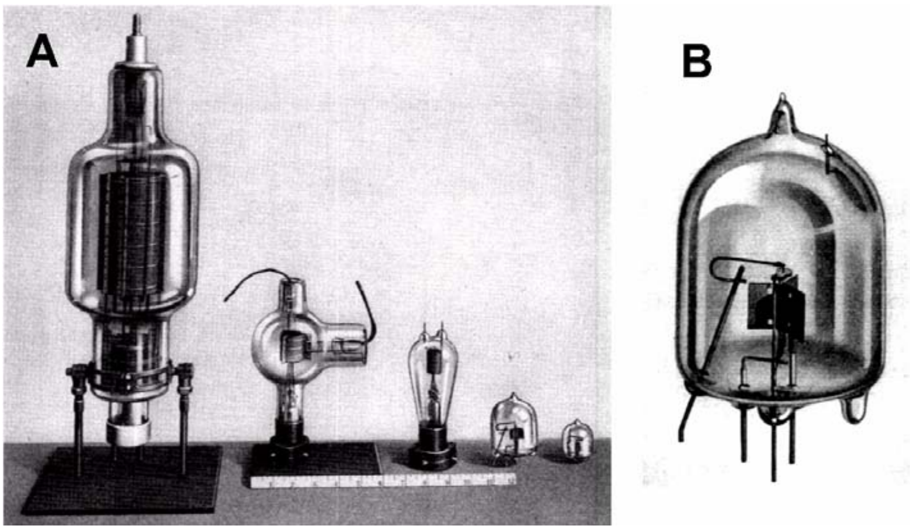


**Fig. 2 - A) Transmitting tubes for increasing frequencies at subsequent decreasing power. From left, 1 kW air-cooled transmitting tube for short waves, the industry standard 852 usable up to 180 MHz, the 304A usable up to 350 MHz. The last two triodes were experimental samples, the last one usable above 1 GHz and delivering 1 watt RF. In B) close-up view of one UHF experimental prototype. Source Bell Telephone Technical Journal.**

The UHF triode visible in fig. 2B would have a considerable impact on early experiments with UHF radio-localization in many countries. We will see that in Germany it led during the war to variants produced in volume for operational radar sets. In August 1936 Western Electric introduced the 316A, the first doorknob-shaped UHF power triode based upon that electrode structure. At the time it was capable of delivering 30 W at 500 MHz and of oscillating up to 750 MHz.

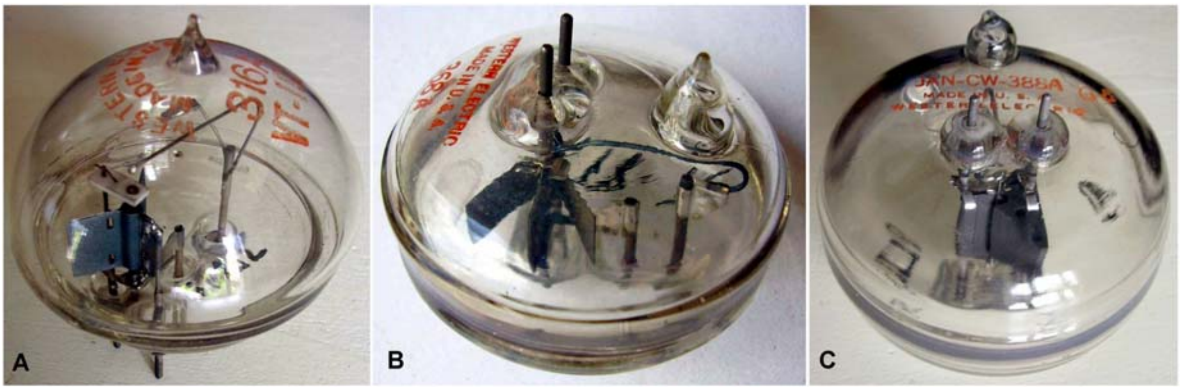


**Fig. 3 - Some Western Electric doorknob UHF power triodes. A) The 316A was first introduced in 1936. It was derived from the experimental type of fig. 2B and could be used up to 750 MHz. B) The double-ended 368A was intended to be mounted in the middle of the resonating lines, oscillating up to 1.750 MHz. C) The 388A was a larger and more powerful double-ended triode with graphite anode. It was capable of oscillating up to 900 MHz, with 50 W plate dissipation.**

In America Western Electric used doorknob tubes until the early 1941 in the CXAS experimental radar. Two triodes generated the marginal peak power of 2 kW at about 700 MHz. The transmitter was then uprated using a cavity magnetron and subsequently doorknobs were confined to applications requiring lower power, as IFF transponders and radar jammers.

In England Bowen tells of his experiments with WE 316A in airborne radars. He started in March 1937 with a single tube oscillator. Few months later his group designed a transmitter with a push-pull of 316As, delivering 1 kW pulses at 240 MHz. Test flights evidenced that the ASV system was less affected by sea-clutter at lower frequencies, around 200 MHz. As consequence, the transmitter was modified to use a push-pull of the cheaper **STC 4304CB**, a rebased variant of the more traditional WE 304A of fig. 1D. Meanwhile Western Electric had introduced new double-ended doorknobs which could operate in the middle of a Lecher line system. The 368A was usable as oscillator up to 1.750 MHz. It was also made as 3B/250A by the related British STC. A larger triode was the 388A, capable of 50 W plate dissipation. We have found evidences of variants, fig. 4C, presumably dating back to around the second half of 1940 and fitted with oxide-coated cathode to drastically increase emission in pulse applications. But by now England had more advanced solutions available to generate strong pulses at even higher frequencies and in June 1941 doorknob tubes were into the Admiralty black list for new designs.

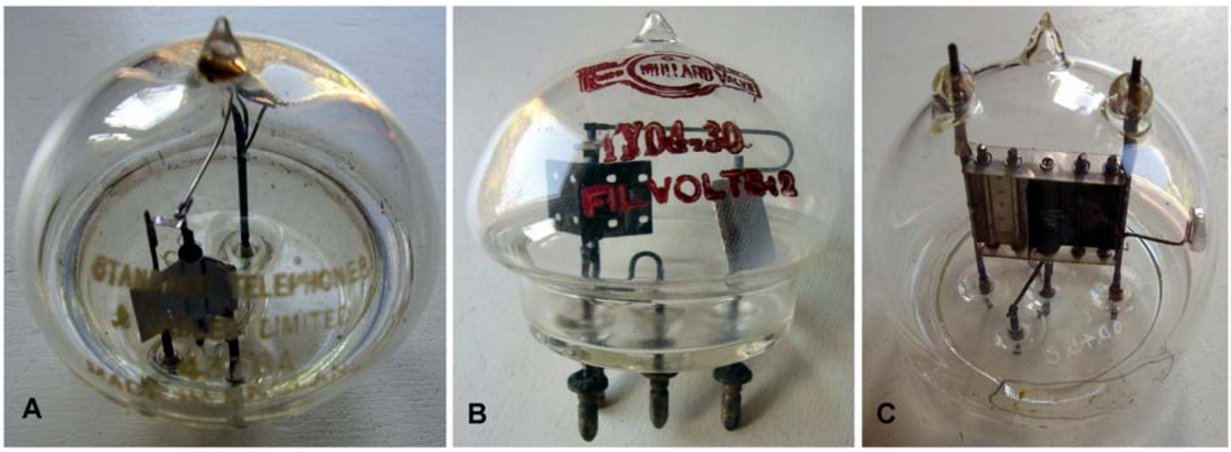


**Fig. 4 - British doorknobs, also known as 'giant acorns'. A) The STC 4316A was identical to the 316A made by the sister company WE. B) Mullard was related to Philips but used its own coding system. Their TY04-30, identical to the Philips TB04/8, differs from the 316A mainly for its thick pins. C) This double ended prototype, variant of STC 3B/250, evidences an oxide-coated unipotential cathode. Probably proposed in the second half of 1940, after the successful tests of this solution in the Megaw's cavity magnetron.**

Although with more or less significant departures from the original Bell design, doorknob tubes found actual application in Germany in the Seetakt marine and coastal-watching radar family. GEMA designed enhanced variants of the WE 316A, the TS1 and the TS1a, the latter one with specular pinout, so that the pair could be mounted back-to-back at both ends of the resonant lines. Plate power dissipation was increased to 40 W and filament current was raised to 6 A in order to increase emission. Seetakt was first installed in 1939 aboard of the Graf Spee. A couple of triodes in the push-pull oscillator delivered pulses of about 1.5 kW at 375 MHz. Such a power proved to be too low, hence from 1941 GEMA introduced the more powerful variant TS6, with eight parallel wires as cathode and 150 W plate dissipation. A push-pull of TS6 tubes generated 8 kW pulses. This tube was also manufactured in Italy by FIVRE, likely for the ‘EC 3 ter - Gufo’ coastal and marine radar made by SAFAR from 1943.

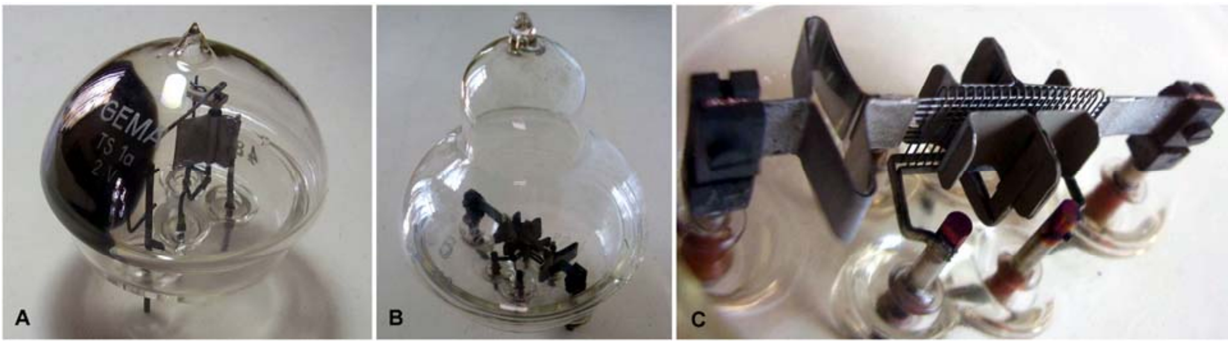


**Fig. 5 - German doorknob UHF triodes. A) TS1 and TS1a, with the specular pinout, were improved copies of the WE 316A introduced in 1939. B) A pair of TS6 replaced the couple TS1 and TS1a in the Seetakt transmitter from 1941. Electrodes were deeply redesigned, with eight parallel filaments to increase emission and a finned plate to grant 150 W dissipation. The strengthened structure visible in C) could withstand heavy mechanical shocks, even those caused by the ship's artillery fire.**


**Fig. 6 - The TU 106 transmitter unit of Seetakt, with two triodes TS6 mounted back-to-back in the push-pull oscillator. The image is reproduced from the US manual TME 11-219, ‘Directory of German Radar Equipment’. According to the today available sources, this unit provided 8 to 15 kW pulses at 375 MHz.**

## Low frequency systems and 'silica valves'

We have said about the early developments of airborne radar sets by the Bowen group. He had to operate at highest possible frequency, mainly to contain the size and hence the drag of the antenna system. As a consequence, he had to accept heavy compromises in the transmitter power. For other applications it was the need to operate at higher power and then at lower frequencies. Early airborne radars as other types for military needs were designed and built by a joint force team stationed since 1936 at Bawdsey Manor. Due to the secrecy surrounding radio-localization, until 1938 development of suitable transmitting tubes was entirely carried out at the HM Signal School in Portsmouth. It was the same structure where, at the end of the Great War, a group leaded by Captain Stanley R. Mullard, who later founded the homonymous tube factory, started building silica valves. Through the years the Signal School group supplied silica tubes for the communication sets of the Admiralty. No wonder than that the first generation of British transmitters for the new systems was based upon silica valves, readily modifying existing types in order to increase their insulation and emission.

For about twenty years, from 1920 to the second world war, silica valves were the pride of British high-power technology. Until 1918 bulbs of transmitting triodes were made of glass, which softened at relatively low temperature. Even if the bulb was large and spaced from the plate enough to reduce heat transmission, power could not exceeded some 500 W. Quartz envelopes were able to withstand high temperatures, softening above 1.000ºC. Even infrared transmission was excellent, an attractive property to facilitate plate heat dissipation by radiation. Mullard had operated before at Edison Swan, developing arc lamps, therefore he decided to use silica bulbs for high-power transmitting tubes. Except for the tungsten filament, which in any case was heated to white heat, all other parts of silica valves were designed to operate at temperatures high enough to melt or soften corresponding parts of any other vacuum tube. Metal parts were of molybdenum, which melts above 2.600ºC. The basket-like plate structure was made of tiny ribbons double-wound on thick ribs, which were firmly anchored to silica donuts fused to the bulb wall. The discontinuous plate surface was semi-transparent to the radiation from the filament, which only partially contributed to its heating. Even the grid was made of molybdenum, its wire being entwined with three or four molybdenum ribs. Higher power water-cooled silica valves were also made, anode being a spiral wound copper tube. Silica valves were difficult to manufacture and so expensive that defective units had to be returned to repair shops.

Plate power dissipation could range approximately from 1 to 15 kW. Size was compact, with considerable benefits at high-frequencies. In 1935, when England started designing early radio-localization sets, the choice for silica transmitting tubes was obvious. Since transmitter had to operate in pulsed mode, peak emission of the tungsten filament was the main limiting factor, by far more severe than plate power dissipation. More or less in the same days other countries had decided to start developing their own systems at frequencies well beyond the upper limits of power tubes then available. Bench prototypes worked with the WE 316A but first operative systems were not ready before 1939, when suitable VHF/UHF triodes were released by tube manufacturers. Much time was spent to solve problems encountered during field tests, as the grid emission when heavily driven positive during RF pulses, the sturdiness of electrodes to withstand mechanical stresses of artillery fire or even simple insulation issues at high voltage pulses. On the contrary in England early systems were designed for frequencies that could be handled by available components, with only minor refinements. Systems were readily operative, contributing to the possibility of evaluating their performance and then to program future evolutions based upon the gained experience. As result, in 1939 other nations appeared to be more advanced, with their UHF radar systems looking better than the old-fashioned English ones. But, without the conditioning of other countries for the rush to obtain results, vacuum tube technologies had progressed more than elsewhere and England was ready to release from 1939 onwards a whole series of innovations, which would culminate into microwave systems since the early 1941.

In 1935 the first system evaluation took place using NT41 short-wave transmitting triodes, slightly modified to withstand 5 kV plate voltage. Filament was over-volted to increase emission.

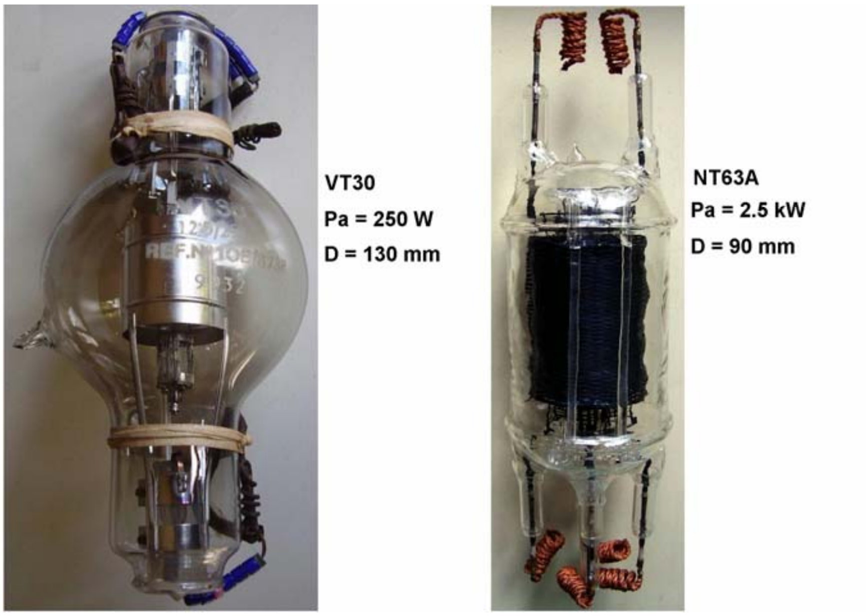


**Fig. 7 - Silica valves were the most efficient air-cooled transmitting tubes available in England in the mid 1930s. Designed at the end of the Great War by the HM Signal School in Portsmouth, their bulb was made of fused quartz, capable of withstand temperatures as high as 1.000ºC. Anode was a double-wound basket made of molybdenum ribbon with three or four molybdenum ribs fixed to the bulb. The grid was made of tiny molybdenum wire, while the filamentary cathode was made of tungsten. Their relatively small size contributed to satisfactory operation at high frequencies. Left, with its 250 W plate power dissipation, VT30 was one of the more powerful transmitting triode with glass bulb at the time of early silica valves. Right, typical 2.5 kW silica transmitting tube made for communication equipment. The bulb diameter measures 90 mm.**

The first triode specifically intended for pulsed operation in radar transmitters was the **NT57**, designed in 1936 by H.G. Hughes at the Signal School. Two V-shaped thick tungsten filaments generated 3.6 A minimum emission. Its electrode assembly was considerably short, to operate well above 45 MHz. Long, well spaced and divergent silica stems for plate and grid connections granted effective insulation up to 10 kV. A couple of NT57 was used from 1937 the transmitters of the CH system (Air Ministry Experimental Station or AMES Type 1). Two NT57s were used in the 50 MHz transmitter of MB2, mobile ground system designed in 1937 at Bawdsey for RAF. The same tubes were used in the Type 79 early warning marine radar, operating at 40 MHz, and in the GL1 and GL2 gun laying systems for the Army. Pulse power greater than 20 kW was readily obtainable from a couple of NT57 triodes in the 7.5 m range.

Early in 1939, NT57 evolved in the improved **NT57D**, with shorter graded-glass seals and emission increased to 5 A. Soon later GEC proposed the **NT57T**, using thoriated-tungsten filament to raise cathode emission to 18 A, while cutting the filament power from 720 to 315 W. A pair of NT57T triodes generated 70 kW peak pulses in the Type 279 marine radar, successor of the Type 79.

In 1937 Signal School released first samples of a bigger silica valve, the **NT60** tetrode which could operate at relatively low anode voltage. Due to its large emitting surface, cathode emission of NT60 was very high, to the point that two tubes in push-pull gave over than 100 kW, about five times greater than that given by a pair of NT57. The NT60 was followed in 1939 by the **NT77**, with thoriated-tungsten filament and emission increased to 70 A.


**Fig. 8 - A) Drawing showing the construction of the NT57 triode, the first silica valve specifically designed for radar applications. Well spaced electrodes and divergent sealing legs grant low capacitance and high insulation. The thick double hairpin filamentary cathode gives 5 A minimum emission under pulsed conditions. B) The photo show a sample of NT57D, with short graded-glass seals, usable up to about 100 MHz. C) It was replaced from April 1939 by the NT57T with thoriated-tungsten filament, capable of delivering 18 A saturated emission, consuming less than half the power required by the filament of the previous one. In D) a sample of CV14 (XN), the latest of compact silica triodes proposed in 1941 to operate up to 240 MHz.**

In Summer 1939 Foley at the Signal School designed a large variant of the NT57, bulb size raised to 100 mm diameter by 300 mm length. With its three hairpin-shaped thoriated-tungsten filaments, the **NT86** was specified for the hard to believe emission of 90 A at 50 kV anode voltage. The triode could handle 4.5 MW input pulses, probably a never surpassed figure for a radiation-cooled tube. In the Type 281 early warning radar a push-pull of NT86 generated 1 MW pulses, when operated at 60 A, 28 kV input. Another monster silica triode, the NT78, was designed to operate as pulser in the modulator. Its development was difficult, due to overheating of the grid, heavily driven positive during conduction pulses. Input and output power of the Type 281 set was limited by maximum ratings of the modulator, to prevent the onset of phenomena of grid emission and surface evaporation which caused filament poisoning. Type 281 radar remained operational until the end of war. A silica modulator tetrode was also developed, remaining operative until the early sixties, when it was replaced by a much smaller hydrogen thyratron. It was the CV313: three of them in parallel generated the 2 MW pulse to drive the magnetron in the Naval Type 992 radar. Silica triodes intended to operate around 200 MHz, as the XL and XN (**CV14**) were also experimented, but they never worked properly and any further development was canceled. The reasons for the cancellation of the silica valves were largely due to the enormous production difficulties, which made them incompatible with the increased military demand after the outbreak of the war. Anyway they had performed their task up to 1940 and in some cases even beyond, allowing the many fixed, mobile and naval systems to be fully operative, with pulse power as high as 1 megawatt.

## External-anode VHF / UHF power electron tubes

In the early 1920s the tube industry started utilizing external anode triodes to handle anode power exceeding about 1 kilowatt. Anode was a hollow copper block sealed to the glass bulb which held the grid-filament subassembly. Copper could be easily worked to any shape, but its extremely high thermal expansion coefficient obstacled sealing to any type of glass. The problem had been solved by W. G. Housekeeper at Western Electric, U.S. Patent 1,294,466 released in 1919. The process involved tapering the copper edge, to form a 'feather-edge', and then sealing the glass to the thin edge, flexible enough to safely relieve stresses due to the different thermal expansion of the glass. Depending upon the power and the selected cooling system, forced-air or water, anode was surrounded by a finned radiator or by a water jacket. In radiation-cooled tubes anode had to be large enough to dissipate heat and the maximum heat transfer is reached when it becomes very hot, up to cherry or even to bright red. Due to the excellent heat conductivity of copper, in external-anode tubes heat was completely transferred to any suitable external radiator. Anode size was then much smaller, a useful feature when trying to design electrode structures of high frequency power tubes.

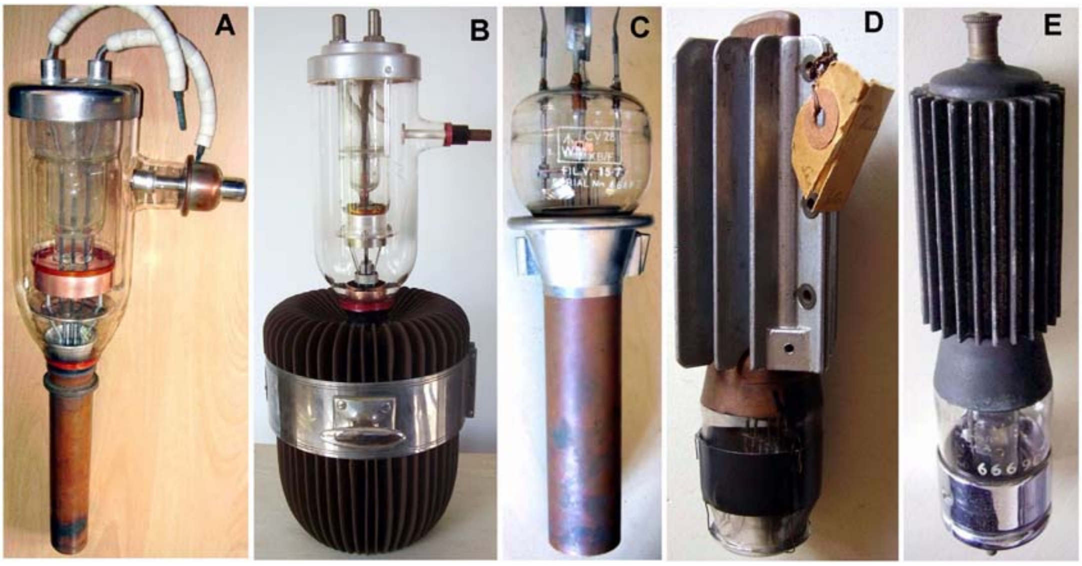


**Fig. 9 - Pre-war external anode power tubes. A) UV-207, also known as 207 or VT-34, was one of the early external anode power triode, introduced since 1923. With external water jacket its plate could dissipate 10 kW. B) The 891R was quite similar, intended for forced-air-cooling. Its heavy finned radiator was rated for 4 kW dissipation. C) In the 1930s GEC was one of the leading suppliers for external-anode transmitting tubes. A sample of STC CV28, without radiator in the photo above, equivalent to GEC ACT9. D) Early in the 1930s GEC also introduced a line of smaller triodes with external anode, referred to as 'Catkins'. Here a prototype with a small finned radiator screwed over the copper plate. E) One of the 'catkin' tubes was this NT39, a compact 75 W transmitting triode capable of operation well over 30 MHz.**

In 1938 at GEC a group leaded by Robert le Rossignol designed an external anode triode intended to replace the 'silica' **NT57,** whose demand by military far exceeded the production capacity. In order to operate in the VHF region were used small electrodes, anode active length being reduced to about 50 mm The E960, approved as VT58 operated up to 23 kV anode voltage, dissipating 750 W with forced-air-cooling. Its tungsten filament required 12.6 V at 58 A. The tube was specified for operation up to 100 MHz but it could be used up to 250 MHz with good efficiency. Not only it replaced NT57 in the existing ground and naval radar sets but it was used at 200 MHz for the prototypes of the coast watching CHL system. A pair of VT58s generated 30 kW typical pulses.

From September 1939, the tungsten filament was replaced by a thoriated-tungsten one. Emission of the new VT98 raised to 25 A at less than one half the heating power of VT58. Although electrodes were only 50 mm high, much less than in other transmitting tubes, with the VT98 the pulse power of the CHL and MB2 transmitters increased to 100 kW. The new triode was widely used not only in England, but also by Canadian REL in its Coast-Defence radar, CD, similar to the British CHL. Lots of the tube were then manufactured as REL-5 by Canadian Westinghouse, some with the dual mark REL-5/VT98. The CD system was also supplied to the United States for the surveillance of the Panama Channel, and other tubes were manufactured by the U.S. Westinghouse, some units with the proprietary marking WL-533.

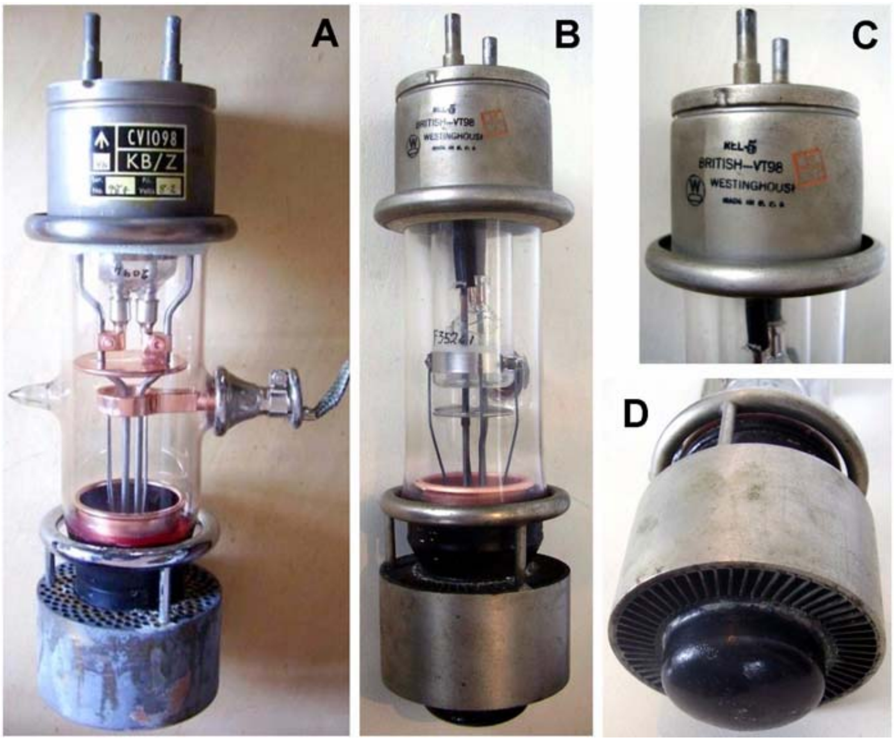


**Fig. 10 - A) GEC built several thousands units of VT98 / CV1098 during the war. In the British tubes anode radiator was made of solid perforated copper. B) This REL-5 / VT98 was made in the U.S. by Westinghouse. C) and D) Details of the Westinghouse tube, showing the double marking, REL-5 / VT98 in this case, and the realization of the finned radiator in place of the British perforated one.**

After the VT58, a larger tube with similar construction was sampled by GEC around August 1939 to replace the NT60 tetrode: it was the E1024, approved as **VT114** with thoriated-tungsten filament granting 70 A emission. In a push-pull oscillator a couple could deliver 400 kW pulses at 50 MHz.

## - The ‘micropup’ and ‘milli-micropup triodes’, 1939 onwards

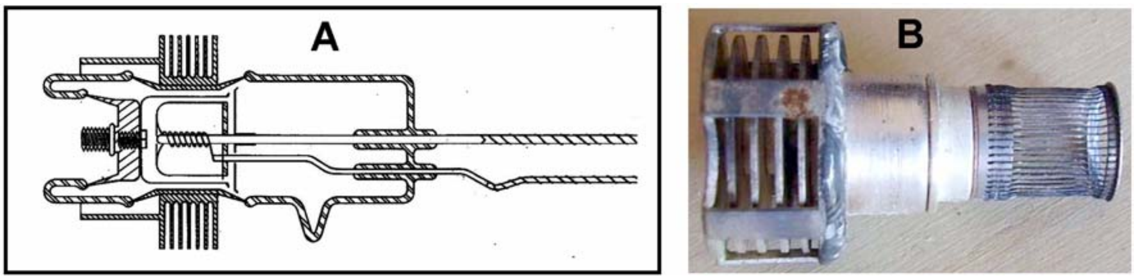


**Fig. 11 - Draft showing the construction of a ‘micropup’ triode and enlarged view of the ‘squirrel cage’ grid of a ‘milli-micropup’ designed to operate up to 1.25 GHz.**

In 1939 at a demand of the Air Ministry GEC introduced a smaller triode with external anode, the E1046, designed by the group of le Rossignol and approved as **VT90**. The triode was intended to replace the **4304CB** in AI and ASV radar sets. Its design was innovative, anode being a small copper tube, both ends being flared and sealed to two glass bulbs. A ‘parrot cage’ grid, made with short molybdenum wires welded along the edge of a small dish, was supported by a rod sealed through one of the bulbs. The cathode was a spiral of thoriated-tungsten supported by two tungsten rods sealed through the opposite bulb. At the end of the manufacturing process, the design granted accurate and close spacing between electrodes. The finned radiator was brazed around the anode. VT90 was rated for 100 W plate power dissipation and 300 MHz maximum operating frequency. Anode voltage could reach 9 kV pulsed, emission being greater than 5 A.

VT90 was favorably accepted, being used in the AI Mk II and in the ASV Mk II airborne sets. About 18.000 ASV copies were also manufactured in America through 1941 by Philco and by Canadian REL. They were known as SCR-521-A or SVC and SCR-521-B or ASE. Lots of tubes were therefore built by local firms, Western Electric, Northern Electric, National Union, Amperex and RCA.

Worth of note is the **CV15**, a conduction-cooled micropup without the finned radiator. The slender shape of its central anode among the two glass bulbs well explains why these tubes were referred to as ‘micropups’.

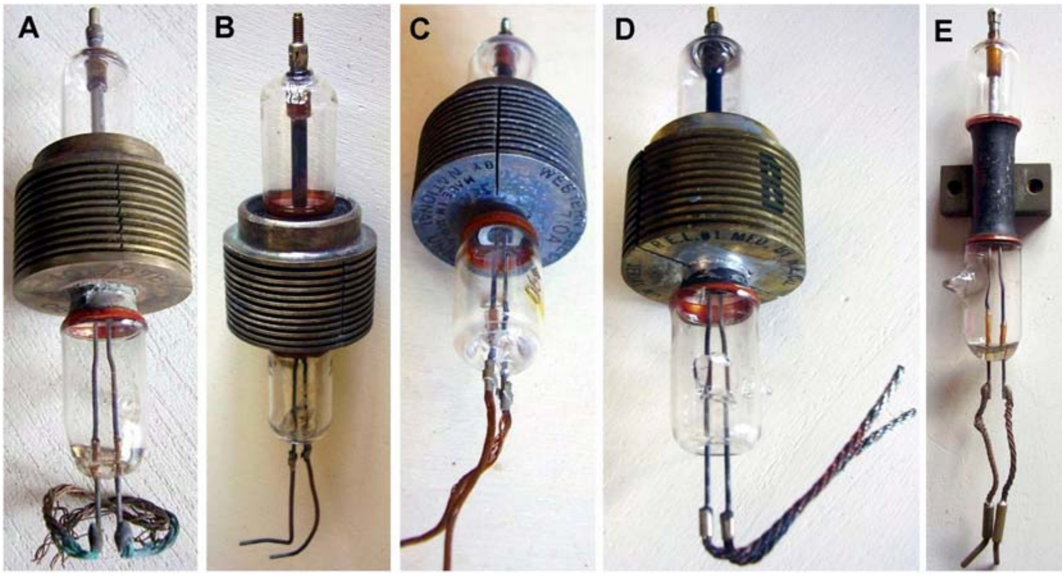


**Fig. 12 - The VT90 and some of its copies and variants. A) Sample of the British VT90. B) In the U.S. RCA, Amperex and National Union built the same triode as 8011. The sample in the above image was made by Amperex. C) Western Electric marked its production with the proprietary code 710A. The above sample was made by National Union for WE. D) This REL Type #1 was made by Canadian Northern Electric, related to WE. E) A sample of the CV15, supplied with a rectangular mounting block to provide conduction-cooling. The block is 15 to 17 mm high, hence we can assume that the anode active length should not exceed 15 mm.**

After the war RCA proposed more powerful variants of VT90 intended for industrial heating, the 6C24 and the 8014. They were uprated respectively to 600 and 400 W dissipation and specified for CW operation. The size of them both was larger than in the original one.

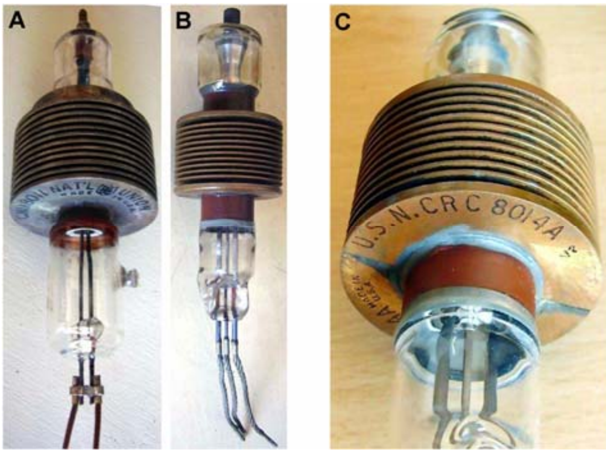


**Fig. 13 - RCA industrial heating triodes A) A sample of 8011 - VT90 as reference. B) The 6C24 shows larger anode diameter, heavy radiator and double CT filament. C) 8014A shows the same large structure.**

## - Oxide-coated cathodes

Until June 1940 cathodes for transmitting tubes were strictly filamentary, at most made of thoriated-tungsten wire. It was common belief that ion bombardment, due to residual gas particles accelerated by the high voltage used in the transmitters, would have destroyed the oxide surface layer. Right at GEC in July 1940 Eric Megaw, with his magnetron **E1189,** had demonstrated that oxide-coated cathodes worked properly in pulsed applications. In fact, heavy ions could never gain harmful speed, provided that high-voltage pulses were short enough.

As a consequence, GEC launched the E1232 design, with the more efficient cathode. First samples were released in April 1941, production starting from July. Internal drawing can be appreciated in fig. 11-A. The cup-shaped nickel cathode was heated by the tungsten spiral inside. The ‘parrot-cage’ grid, similar to the one in fig. 11-B, was tightly screwed to the connecting copper plate, sealed to a folded glass spacer. The whole assembly was extremely rigid, electrodes being very closely and precisely spaced. The tube operated up to 600 MHz, pulsed to 8 kV with 40 A emission. Two tubes in push-pull generated 150 kW at 200 MHz and about 100 kW at 600 MHz. Approved as NT98, its success was even larger than that of VT90. It was used in several ground, naval and airborne sets at 200 and 600 MHz. It was also used in Canada and in the U.S., where it was built by National Union and Central Electronics as 4C27, by RCA as 8026 and by Rogers as REL 7.

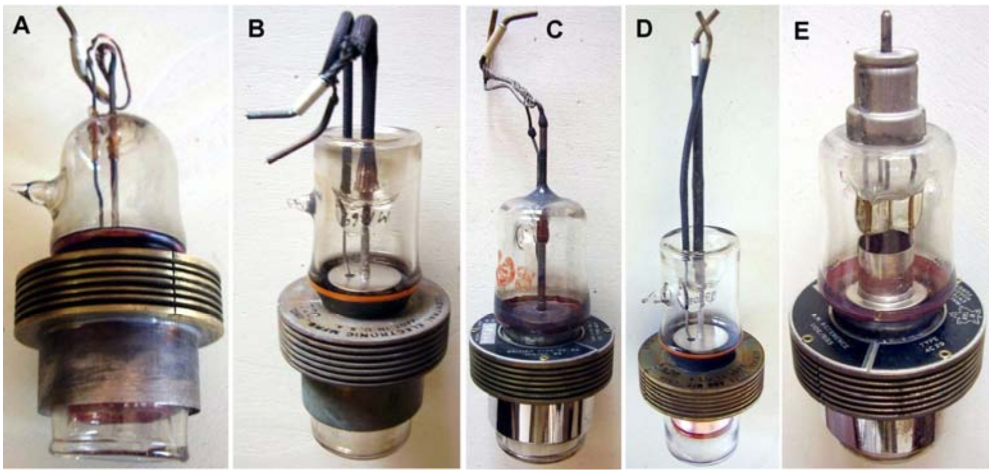


**Fig. 14 - NT99 and its variants. A) The British NT99. B) A quite late sample of 4C27 likely made in the fifties by Central Electronics. C) A Canadian REL 7 made by Rogers. D) During the war RCA introduced the 4C28, a variant of NT99 designed for its SHORAN navigation and bombing system. The system was used after the war for oil exploration. E) 4C29 was made in Canada by Rogers for REL and was also registered in the U.S.**

In April 1944 GEC started designing a new micropup triode, released shortly before the end of the war and believed to be the largest one ever built. With its massive radiator the E1495, approved as CV240, was specified for 1 kW plate power dissipation, 15 kV anode voltage and 125 A minimum emission. It could be used as pulsed oscillator up to 100 MHz. Other structures were also defined, capable of operating at 600 MHz and up and readily adaptable to coaxial resonators. The CV288 was designed in 1943 and tested at TRE, generating 50 kW peak output. There was no operational use during the war but the tube was proposed again as ACT25 after the war. It was screened for CW operation, as wide-band UHF amplifier for TV repeaters. The same electrode arrangement was retained in the post-war CV2200/CVX2200, which could operate as pulse oscillator up to 1.5 GHz.

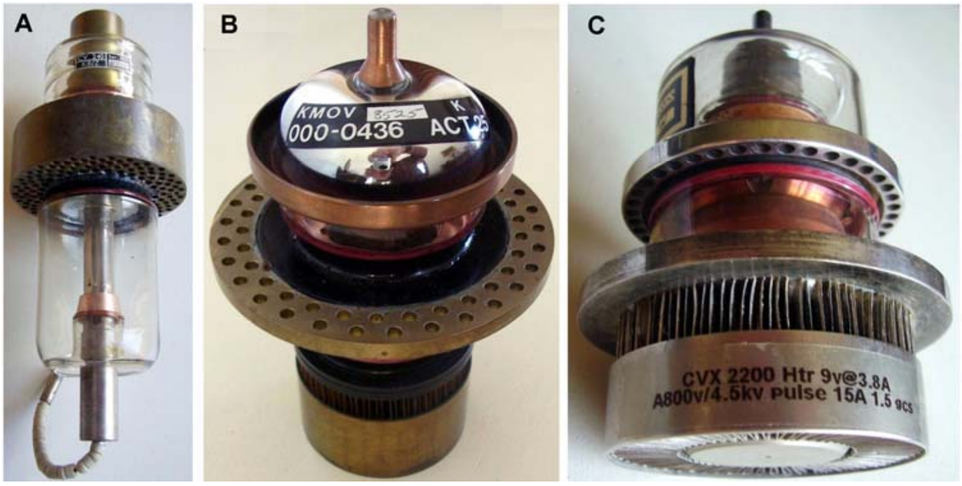


**Fig. 15 - A) CV240 was the largest micropup triode ever made, weighing about 1.2 kg. B) The basic shape of the external anode triodes was modified to design tubes adaptable to coaxial resonators, as this ACT25 derived from the CV288. C) The same structure was retained in this CVX2200, capable to operate up to 1.5 GHz.**

## - Milli-micropups

A little known family of UHF triodes was that referred to as 'milli-micropups', whose design started early in 1940. In response to the request of Air Ministry for a system operating at 10 cm wavelength, GEC proposed the development of power triodes capable of operation at 25 cm, or 1,200 MHz. First laboratory samples were ready since March 1940 and an experimental system was already installed on the roof of the Wembley Laboratory in the summer, when Megaw started testing his magnetron. Subsequent development stages up to the production were delayed, after Megaw's magnetron had run at 10 cm beyond all expectations. Production of E1190, tested and approved as **CV55** for CW and as **CV155** for pulse operation, only began in 1941. Although a pair of tubes could generate 40 kW at 1.2 GHz, they were used only in niche applications, such as IFF transponders. An high-gain variant was the **E1458/CV178**, rated both for CW and pulse operation. Based upon the E1458, National Union in America designed its own 3C27, with coaxial heater-cathode connector. 3C27 was modified to 3C27B, adding a radiator on the grid, and then to 3C37, which was advertised at the end of the war as capable of generating 10 kW pulses at 1.150 GHz. National Union also registered the small 3C36, an improved design whose experimental code was R1001. Its was specified for pulse operation between 500 and 1500 MHz. Emission was as high as 50 A. It could accept a forced-air cooling radiator up to 200 W or a water jacket, power dissipation raising to the exceptional value of 500 W.

Performances of the milli-micropups stood unsurpassed until the appearance of power planar tubes. To understand how advanced this family was, we must consider that when it was designed, in 1940, the best German UHF triodes, the **LS180** and the **TS1**, could operate up to about 600 MHz, RF power not exceeding 8 kW at the best. Western Electric itself in the U.S. had nothing better than doorknob tubes and the transmitter of the experimental radar CXAS in October 1940 could generate only 2 kW pulses at 700 MHz, using four triodes in its ring oscillator.

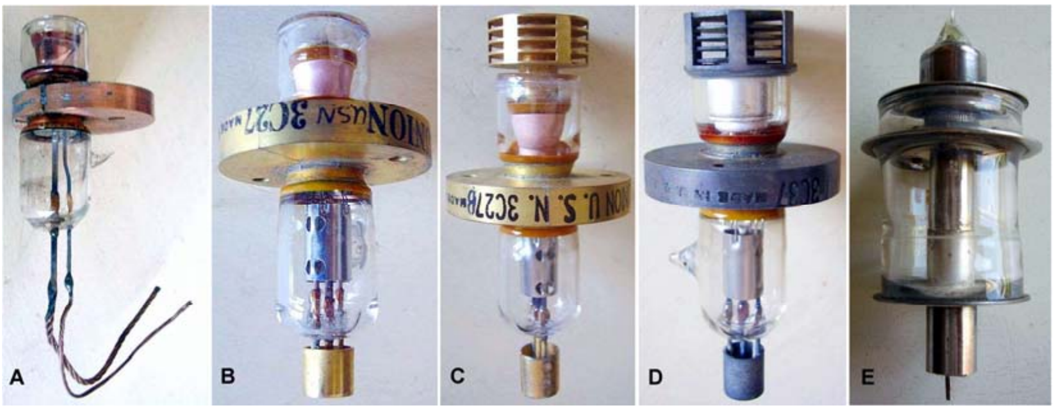


**Fig. 16 - A) Anode of [CV155](), E1190 tested for pulse applications, was only 7 mm high. B) National Union [3C27]() evolved in the [3C27B]() (C) with the top grid radiator, to prevent grid emission when heavily driven positive during pulses, and then in the [3C37]() (D). E) A rare sample of the tiny National Union [R1001](), registered as 3C36.**

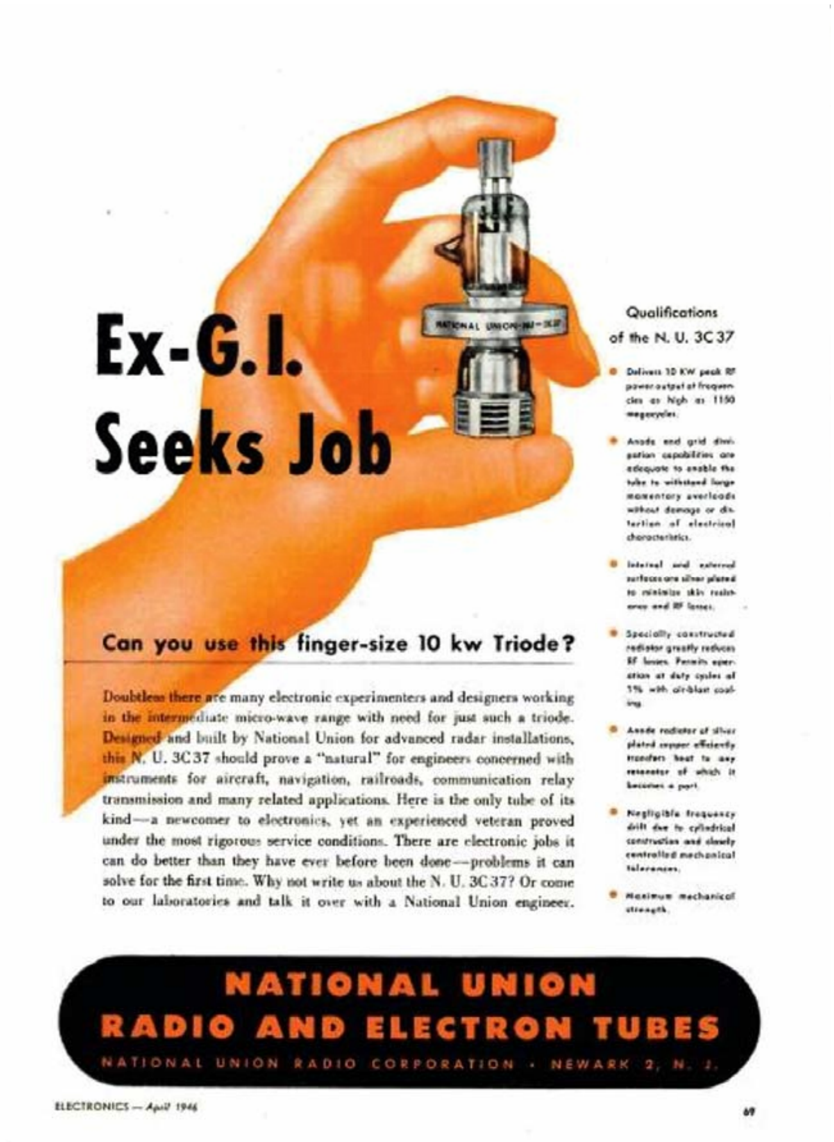


**Fig. 17 - The National Union ad for its 3C37, from April 1946 issue of Electronics.**

**To be continued...**