4 - Transmitting tubes

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This is a quite large section, since it includes most of the space charge tubes intended to operate in broadcast or communication transmitters over wide ranges of power and operating frequency. Listed types include some audio tubes which were commonly used as modulators or as RF power amplifiers. Even some receiving tubes can be found in this section if they were used in low-power transmitters. Boundaries between this and other sectors man be rather vague. For this reason maybe that some tubes are even listed elsewhere or that some special types, those designed for extremely high frequencies or for radar pulsers and pulse transmitters, can be only found in their respective sections.

The collection includes many types which can be dated from the Great War up to the sixties. Most of the exhibits were build using glass bulbs, offering a glimplse of the inside and often revealing otherwise unobtainable details about shapes and arrangement of electrodes.

Early transmitting tubes on display are some low-power types, as VT-1, VT-2 and the VT-14, also referred to as CG-1162. Indeed, in the golden age of wired communication, among the early applications of transmitting vacuum tubes there was a need for small radiotelegraphic sets with RF power of very few watts to communicate from observer airplanes or aerostatic ballons to ground, where laying of cables wa/s impractical. High power tubes required large bulbs, difficult to evacuate. The same surface of metal plates, reaching high operating temperatures, contributed to free gas inside the envelope. Power transmitters were still using spark gaps to generate more or less damped oscillation in large installations. Nevertheless the war had pushed the research for more agile long distance communication. This was particularly true for British Admiralty whose battheships operated far away on the oceans. The collection includes samples of power transmitting tubes introduced from 1918 to 1922, among which we find the fine AT50 and the MR1 rectifier.

Fig 4.1 - Transmitting tubes from the Great War. A) Western Electric VT-2 was manufactured for Signal Corps since 1917. B) General Electric VT-14 was a low power oscillator. This early version, still looking as the VT-12, was made around the late 1917. C) The improved and ruggedized version of VT-14 was produced starting from 1918. D) AT50 was a power triode made for British Admiralty, probably from 1918. E) This British MR-1 rectifier apparently was introduced in 1918 or soon later.

Another family of high power transmitting tube was introduced just after the war by Captain Stanley R. Mullard, who had previously designed power vacuum tubes for Admiralty. New tubes, known as ‘silica valves’, were made using fused silica instead of glass. High melting temperature of silica made possible to build compact envelopes with walls close to the plate operating at red temperature. Silica valves were so expensive due to difficulty to mold the fused silica envelope that, when removed from service, they had to be returned to a repair shop. In the collection we find two samples of silica valves, the NT45A and the TYS5-2000.

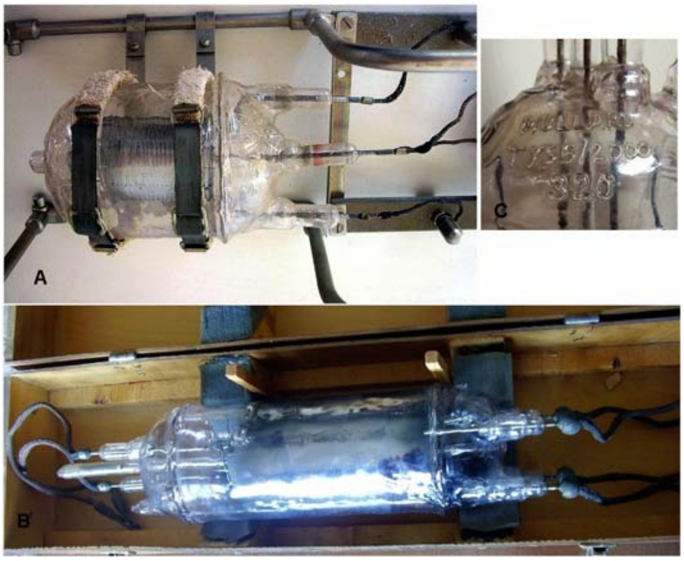

Fig. 4.2 - Due to the high melting temperature of the envelope, silica valves were relatively small, their diameter just being slightly greater than the plate diameter. A) NT45A was a quite small transmitting triode, rated for 1.25 kW power dissipation. B) TYS 5/2000, rated for 2 kW dissipation, is 477 mm long. C) Close-up view of the hand made writings in fused silica. (Click on the image to enlarge)

In America the production of more powerful tubes between the two wars saw a quick settlement of glass models, with most of basic types introduced in the early twenties and continuous small improvements in materials and in processes through the successive years. The medium power 'fifty watter', the 211A, was introduced by Western Electric in 1921. After several improvements, as 211B, 211C, 211D, 211H and 211Spl also marked VT-4C, it was still one of the most popular power tubes in production in the fifties, more than thirty years later, and still today manufactured in China for guitar amplifiers. Variants uprated or even derated of the same basic type, retaining the same shape and the same filament ratings, were proposed for specialized applications requiring different gain, interelectrode capacitance or capability to withstand overloads, as in industrial heating. Among the countless variants, we could see the 261A, capable of operating at 30 MHz full ratings and the 845, derated for audio applications.

A family of larger tubes derived from 212A, a power triode rated for 250W plate power dissipation. 212A in 1924 was replaced by the thoriated tungsten 212B. This tube was forerunner of several copies and variants, as the Mullard MZ2-200. Another style of 250 watter was represented by the UV204 introduced by RCA in 1921 as capable of operating at 250W plate dissipation. UV204 was fitted with a pin-and-blade base and had to be operated upside down. In 1923 it was followed by the improved 204A, with thoriated-tungsten filament.

Any further increase of power was related to the development by W. Housekeeper at Bell Telephone Labs. of a reliable process to seal glass to copper surfaces. This, also known as 'feather-edge' sealing process, led to the introduction of power tubes with external copper anode. Radiation cooling through the glass wall had imposed severe limitations to the power that could be safely handled by tubes with acceptable plate and bulb size. In external anode tubes heat could be now efficiently removed directly by cooling fluids, as forced air or water, flowing around the outside wall of the copper anode. Power ratings increased enormously and powerful broadcast transmitters were put in service, using tubes capable of dissipating kilowatts or tens of kilowatts. British GEC was the first to adopt in the early thirties the new sealing process even in smaller tubes, with the so called 'catkin' family and a few transmitting tubes as the NT39.

The addition of a second grid simplified the circuitry in ham and small voice transmitters, making it possible screen grid modulation. Among the screen grid transmitting tubes remarkable are the VT31, the ATS70, the 282A and the RK-65.

A tendency in British military small power tubes up to 50W was the adoption of the unique L4 base. We find some samples of these quite rare types, as the U15 rectifier or its ruggedized version NU13A, the VT13C and the VT25 transmitting triodes and even a tetrode, the ATS70, actually a rebased WE 282A.

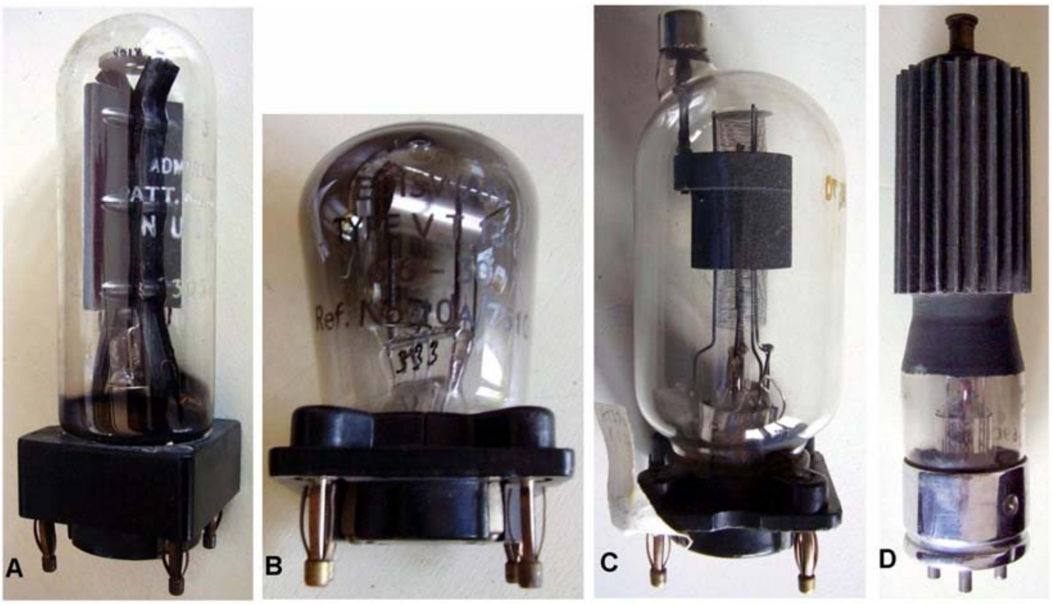

Fig. 4.3 - Samples of L-4 base British power tubes. A) - NU13A was a ruggedized power rectifier. B) - A sample of VT13C, about 1925. C) - The ATS70 actually was a rebased WE 282A, early thirties. D) The relatively small external anode NT39, Admiralty pattern 813, was rated for 75 W plate dissipation. (Click on the image to enlarge)

The collection includes several medium and high power tubes with external anode. Among the water-cooled types we could see types listed the following table:

3F20TA	Fivre	22 kW, 30 MHz
3F22TA	Fivre	22 kW, 25 MHz, folded anode
846	Machlett	2.5 kW, 50 MHz
880-GL	General Electric	20 kW, 25 MHz, folded anode
893B	Fivre	20 kW, 5 MHz
5668	Westinghouse	20 kW, 5 MHz
7255	Westinghouse	9 kW, 30 MHz, integral jacket
8592	Amperex	6 kW, 55 MHz, integral jacket
F-129B	Federal	7.5 kW, 30 MHz
TAW12-20	Philips	18 kW
VT-34 / JAN-207	Federal	10 kW, 1.6 MHz

Fig. 4.4 - Water-cooled transmitting tubes. A) - The Fivre 3F22-TA / 5771 is an improved version of the folded anode 880, 22.5 kW. B) - VT-34 / JAN-207 is rated for 10 kW anode dissipation. C) The smaller 846 was rated for 2.5 kW. D) The heavy 5668 was capable of dissipating 20 kW through an external water jacket. F) The integral jacket Amperex 8592 was rated for 6 kW anode dissipation. (Click on the image to enlarge)

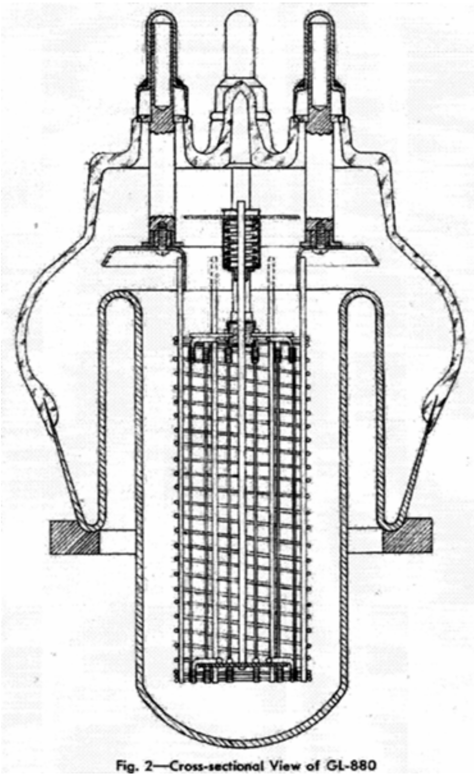

Fig. 4.5 - Cross-section of folded anode triodes, as 880 and the same 3F22 TA. (Click on the image to enlarge)

Forced-air-cooled transmitting tubes include small power devices, under few hundreds watts, as well high power ones, over some 500 W. Among the small power tubes, the following ones are of particular interest, as prototypes of successful families or simply for their outstanding performaces.

2C39	GE, CW design	100 W, 500 MHz, 'oil-can', forerunner of countless variants, 2C41, 322 diode, 381, 7289, 7698, 7815, 8906
3C22	GE, pulsed opr.	125 W, 1400 MHz, 'lighthouse'
4C28	RCA	150 W, 250 MHz, Shoran 'micropup'
4C29	REL Canada	150 W, 600 MHz, 'micropup'
4C33	RCA, pulse	250 W, 625 MHz
4X150	Eimac	150 W VHF tetrode, forerunner of countless variants, among which 4CX125, 4CX250, 4CX300.
4X500	Eimac	500 W, 120 MHz
6C24	RCA	600 W, 160 MHz, 'micropup'
5946	RCA, pulse design	250 W, 1250 MHz
6161	RCA, CW design	250 W, 900 MHz
6263	RCA	up to 13 W @ 500 MHz, 'pencil'
8014	RCA, pulse design	400 W, 'micropup'
ACT25	GEC	450 W, UHF amplifier
NT99	British GEC	150 W, 600 MHz, 'micropup' style, forerunner of CV92, CV199, CV1256, 4C27, REL-7
VT90	British GEC	100 W @ 300 MHz, 'micropup' style, forerunner of 710A, 8011, REL-1

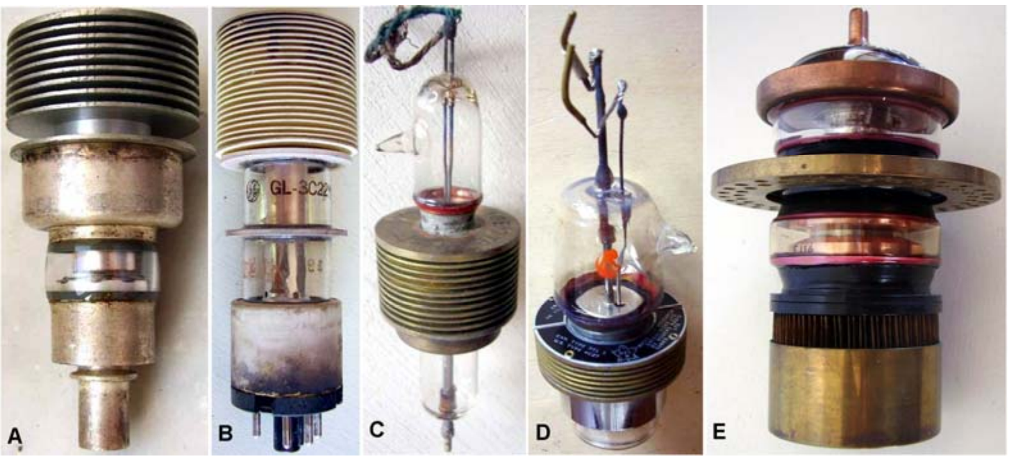

Fig. 4.6 - Small forced-air-cooled transmitting tubes. A) 2C39 'oil can' style, introduced by General Electric during WWII, was one of the most successful tube designed, with countless variants and improvements. B) GE 3C22 was a transition between the low-power 'lighthouse' tubes and the 'oil can' of the previous exhibit. C) British VT90 was the VHF power triode used as power oscillator in most of the Allied airborne radar sets until 1941. In D) we see a sample of REL-7, the Canadian production of the British NT99 which replaced VT90 and was also used in naval and artillery radar sets. E) The ACT25 was a VHF power amplifier derived from the CV288, a powerful triode for pulse applications developed in 1945. (Click on the image to enlarge)

The variety of forced-air-cooled tubes dissipating over than 1 kW is even larger. Usually they are fitted with a finned copper radiator. These types are of particular interest even for the difficulties to collect them because of their high starting price, of their fearful packing and shipping cost and of high risk of damages by carriers.

3CX3000FI	Eimac cermet	3 kW, audio modulator
3F3-TRX	Fivre	3 kW
3F6-TRX	Fivre	6 kW, industrial heating
7C24 / 5762	RCA	3 kW, TV VHF repeaters
891-R	Fivre	4 kW, up to 18 MHz
5513	GE coaxial	1.2 kW, 220 MHz, TV repeaters
5680 / 7C23	Federal	2.5 kW, 30 MHz
5760	Amperex	2 kW, 150 MHz, external radiator
6076 / QBL5/3500	Amperex	3 kW, 220 MHz
6961	STC / Amperex	6 kW, 30 MHz
7883 / BR-169C	Marconi Genova	1.5 kW, audio modulator
8002-R	Amperex	1.2 kW, 110 MHz
ACT28	GEC	1.5 kW, 600 MHz
ATL2-1	BBC	2 kW, 70 MHz
BTL1-1	BBC	1 kW, 220 MHz, TV repeaters
CV28	STC	1.1 kW, external radiator
CV1098	MOV, pulse design	750 W, 100 MHz
FTL 3-1	BBC	3.5 kW, 60 MHz
FTL 3-2	BBC	5 kW, 60 MHz
FTL 8-1	BBC	8 kW, 60 MHz
GL-434A	GE, pulse	1.2 kW, 5 MHz
ML-7003	Machlett, pulse	3 kW, 80 A emission, screened grid
RTH-11	IAE-Milan	10 kW
TAL 12/35	Philips	18 kW, 37.5 MHz
TBL 6/14	Philips	up to 25 kW, 30 MHz, industrial heat

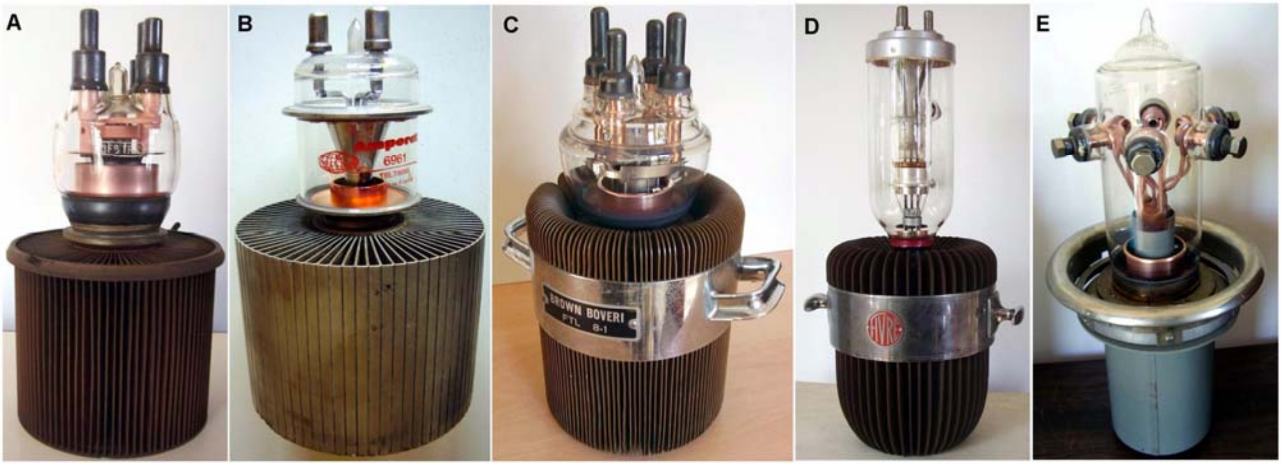

Fig. 4.7 - Forced-air-cooled transmitting tubes. These tubes were usually mounted upside-down, as shown in the above photos, the finned copper anode radiator being plugged into a cooler housing. A) A 6 kW 3F6-TRX made by Fivre. B) This Amperex 6961 or TBL 7/8000 can dissipate 6 kW and operate up to 65 MHz. C) The 8 kW Brown Boveri FTL 8-1 weighs 13.5 kg. D) This 4 kW 891-R made by Fivre is 559 mm high and weighs 20.4 kg. E) The TAL 12/35 made by Philips dissipates 18 kW and weighs 20 kg. (Click on the image to enlarge)

Even conduction-cooled tubes were designed to be mounted into hermetic enclosures, heat being transferred to external radiators through the metal wall:

3C27 / **3C27B** / **3C37**	National Union	'micropup'
7698 / **7815** / **8906**	U.S.	'oil-can'
CV15	GEC	'micropup'
CV55 / **CV155**	GEC	'micropup'

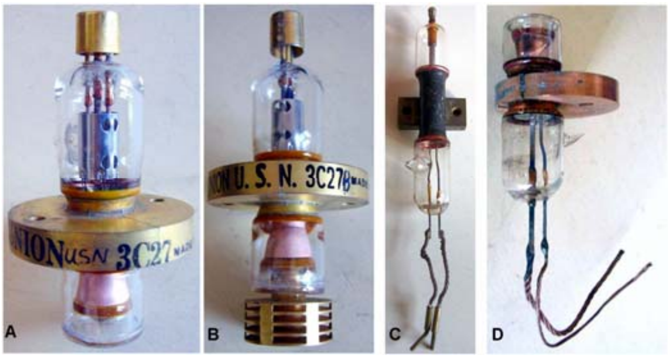

Fig. 4.8 - Samples of conduction-cooled transmitting tubes. A) A rare sample of 3C27, derived from the British CV55 and superseded before going in volume production by the 3C27B (B) with grid radiator and soon later by the 3C37. C) The CV15 is similar to CV90, a small bracket replacing the finned radiator. D) The millimicropup CV155 was rated for operation at 1200 MHz, generating 40 kW pulses. (Click on the image to enlarge)

After the thoriated-tungsten high-efficiency filament, other major improvements were introduced from the mid twenties in the transmitting tubes. Better materials were found either for glass envelopes and for plates. Glasses as 'Pyrex' or 'Nonex' were by far more easy to handle than silica, yet were characterized by a failrly high melting temperature. Anodes made of graphite were capable of withstanding high temperatures without warping or melting. Even better metals like tantalum or molybdenum could safely operate at cherry-red temperature, at the same time acting as getters. Most of these materials were used in American tubes intended for radar and communication transmitters during WWII.

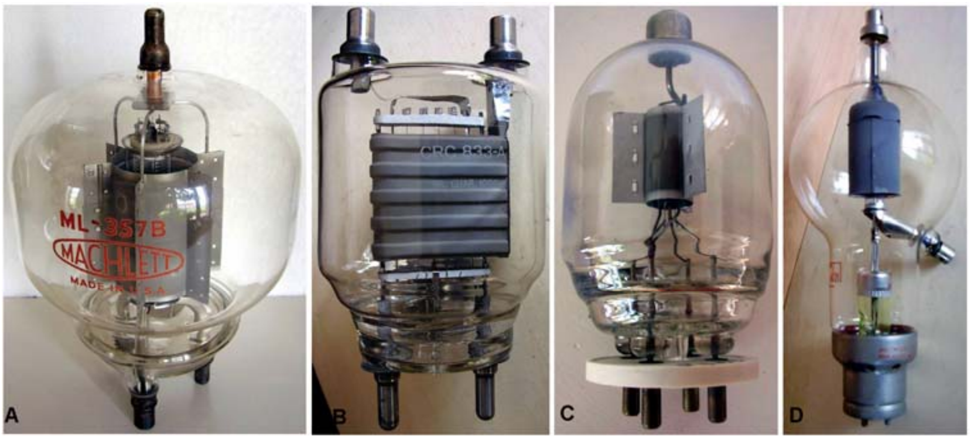

Fig. 4.09 - Some American transmitting glass tubes in use in WWII. A) The 357A, 400 W plate dissipation, was registered in 1943. In the photo a sample of the 357B. B) RCA introduced the 833 in 1937. The improved 833A, rated for 400 W plate dissipation, was registered in 1943. C) The WE 356A was introduced around 1938. Six 356A tubes were used in the pulse modulator of the CXAS and Mark I radar sets. The gridless version, known as 705A was one of the most successful high-voltage rectifiers used in radar modulators. The sample in the photo is a 357B, registered in bulk to Western Electric only after the war, in December 1945. D) The 6C21 was a variant of the Eimac 1000T, uprated to operate as radar pulse modulator. (Click on the image to enlarge)

The above said improvements led to the introduction of compact tubes, with small electrodes, capable of operating in the VHF or even in the UHF region. Many types were introduced in America as alternate solutions to the British micropups in radar transmitters. UHF transmitting tubes were used even in Germany through WWII.

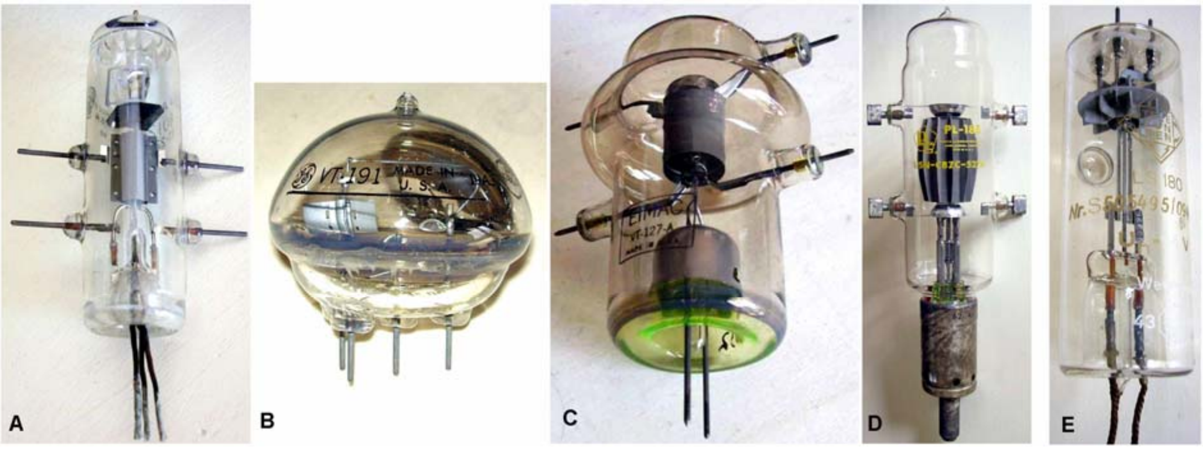

Fig. 4.10 - Some VHF / UHF transmitting tubes used in WWII radar sets. A) When 8012 is operated at full ratings, plate shows orange-red color. B) 316A / VT-191 is one of the ‘doorknob’ family tubes introduced by Western Electric in the mid thirties and capable of oscillating in the UHF region. Doorknob triodes were used in the very early British aviation radars and in German sets. C) VT-127A was one of the many UHF triodes all using the electrode syatem of a standard transmitting tubes in a special envelope, with grid and plate pins placed to match the external resonating line. E) 527A / PL-185 was a high-power triode intended for pulse operation. Four tubes in a ring oscillator generated 1 MW RF pulses in the AN/TPS-18 radar. It was also used as pulse modulator, being capable as switch of delivering 100 A pulses to the load. E) The LS-180 was a German tube used at about 600 MHz in the transmitter of the Wurzburg radar. (Click on the image to enlarge)

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