Silica valves

The technology of silica valves was developed by the Admiralty Signal School at the end of World War I. For power transmitting tubes silica was superior to glass for several aspects. Silica has a softening point much higher compared with that of glasses. Internal electrodes can operate at temperatures close to white heat, so to improve radiation cooling of the plate while bulb remains considerably cool, since silica walls transmit very well in the IR spectrum. For its properties silica bulbs could be made much smaller than glass ones, leaving few millimeters between their internal wall and anode. Silica has considerably lower thermal expansion than glass, about one tenth, so reducing risks of cracks due to thermal stresses and shocks. It is mechanically stronger than glass and it has excellent insulating properties. For its properties silica was considered by the British Admiralty the best solution for the bulbs of short wave power transmitting tubes.

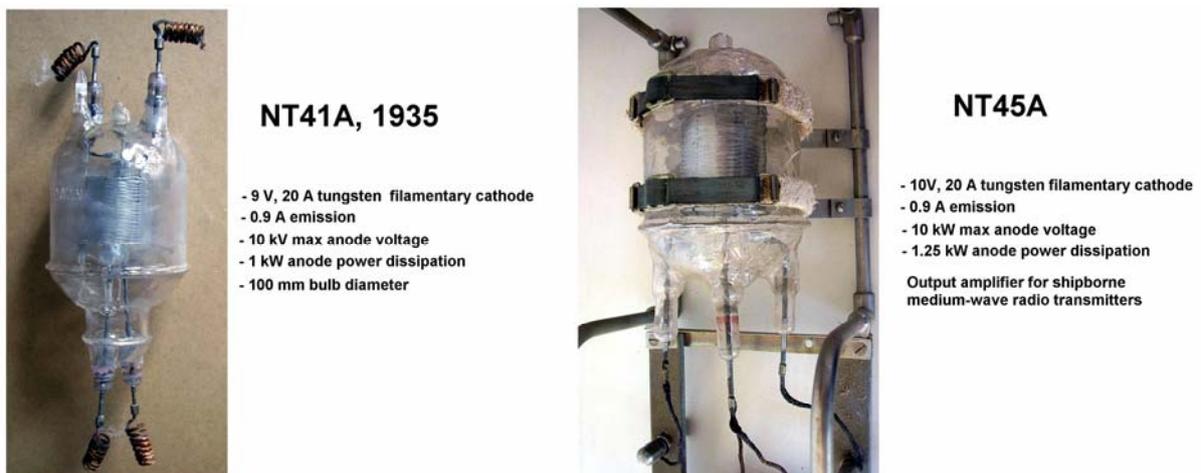**Fig. 1 - Early transmitting tubes: in A the 250 W VT30, in B the 600 W MT9A and in C a 2 kW silica triode.**

The above fig. 1 shows two 1920s glass transmitting tubes compared with a 2 kW silica triodeon the right. Net of exhaust pips and other protrusions, the body diameter measures 150 mm for the 250 W **VT30** triode, 260 mm for the 600 W **MT9** and only 110 mm for the silica 2 kW triode.

In silica valves anode was made of 2 mm by 0.1 mm molybdenum ribbon, woven in a basket-like cylinder all around a skeleton made by molybdenum rods. Grids were made of molybdenum wire, spiral wound around ribs of the same material. Filament was made of tungsten wire, thoriated-tungsten being used from 1939 onwards. Longer rods in the electrode ribs were terminated into silica spacers welded to the inner wall of the envelope to firmly hold them in their right seating.

Soon after the war Captain Stanley R. Mullard, who had worked to the development of such tubes, founded the Mullard company, to build silica valves. Their manufacture remained a painstaking job and just the British Admiralty could afford their fearful cost. For their cost, silica valves removed from service had to be returned to equipped workshops in order to be repaired. Silica valves were also used in the early radiolocalization experiments. Early experiments on radiolocalization by the reflection of short radio pulses had been performed by Watson-Watt in 1935 using a low frequency transmitter equipped with these valves. Similar experiments were then successfully repeated to detect airplanes. Transmitting tubes modified for pulse applications were then developed, capable of operation at higher voltage and current than the communication ones. Until 1938 none of the tube manufacturers had access to information on RDF experiments, hence the use of silica valves in the early secret sets was decided mainly because these tubes were developed and manufactured in a naturally secure Service Laboratory at the Signal School.

As said before, special features were required for power tubes to be used in RDF transmitters. They had to generate RF pulses of few microseconds. Generally, since the signal attenuates with the fourth power of the distance, very high power pulses had to be transmitted, hence tubes had to operate at very high voltage and current. Therefore both the insulation between electrodes and the cathode saturated emission had to be increased. Working with low duty pulses, anode dissipation did not generally represent difficulties. Certainly more severe were the problems arising from the grid overheating when heavily driven positive during the conduction. Anyway transmitting tubes for RDF use had to operate at the highest possible frequency. In the case of silica valves the frequency limit was somewhere between 50 and 100 MHz, even if types intended for operation up to about 200 MHz were proposed.

The early triode adapted to operate in radar pulse transmitters was the compact **NT41A**, developed from July 1935. It was readily derived from the NT41, originally designed for short wave shipborne radio transmitters, improving the insulation for operation at 5 kV. As we can see from its photo in fig. 2, actually only the spacing between the grid and the anode output stems was increased. Early six samples were asked to the Signal School for deliveries between September and October 1935. NT41A was used in early trials from 8-metre down to 4-metre wavelenght, while unmodified NT41 transmitting triodes were used for trials at lower frequencies.

NT41A, 1935

- 9 V, 20 A tungsten filamentary cathode
- 0.9 A emission
- 10 kV max anode voltage
- 1 kW anode power dissipation
- 100 mm bulb diameter

NT45A

- 10V, 20 A tungsten filamentary cathode
- 0.9 A emission
- 10 kW max anode voltage
- 1.25 kW anode power dissipation

Output amplifier for shipborne medium-wave radio transmitters

Fig. 2 - Lefrt, the NT41A for pulse operation. Right, the NT45A for CW communication transmitters

Looking at the NT41A and at the few data available, we are do not appreciate any departure of the electrode assembly from that in use for short wave radio transmitters. Even the emitter was still the low emission one of basic silica triodes for shipboard radio communication, such as the single-ended **NT45A** on its right. Then we must assume that early developmenal RDF transmitters generated pulses under 10 kW.

One of the silica valves specifically designed for generating high-power pulses in radar transmitters was the **NT46R**. The emitter was still a single hairpin, as in previous transmitting triodes, but the size of the tungsten wire had been increased and consequently its surface could grant 3 A emission. The plate power dissipation too was raised to 3.5 kW to safely handle pulses up to 20 microseconds wide. NT46R was used in several early radar sets, as the MB1 and MB2 designed at Bawdsey for the RAF in 1937 and in the GL1 and in the GL2 designed soon later. According to Callick, in many cases NT46R was used as driver for a couple of more powerful NT57s in the output stage.

NT46R

15 V at 40 A tungsten filamentary cathode
3 A cathode emission

3.5 kW plate power dissipation
10 kV anode voltage

Fig. 3 - The NT46R, designed for pulse operation

Even the design of the more powerful NT57 was started in 1936 by H. C. Hughes at the Signal School. In order to increase the upper frequency limit, the use of short electrodes in a compact envelope was preferred. The single hairpin filament of the NT46 was replaced by a couple of tick filaments resulting in a saturated emission of 5 A. At the same time the grid and the plate output stems were very well spaced from each other, to improve insulation.

NT57D

- 15 V at 48A double hairpin filamentary cathode
- 5 A emission
- 10 kV anode voltage
- 1.75 kW anode power dissipation

Note: graded glass seals

NT57T

- 9 V at 38A double hairpin filamentary cathode
- 18 A emission
- 10 kV anode voltage
- 1.75 kW anode power dissipation

Note: thoriated tungsten filament

Fig. 4 - The NT57D with tungsten filament and the thoriated-tungsten variant NT57T.

NT57 was used in several radar sets. In the Type 79 first shipborne radar a couple of NT57s, operating around 40 MHz in a self-oscillating push-pull circuit, generated 15 kW pulses with a duration from 5 to 20 microseconds and a recurrence of 50 p.p.s.

Early in 1939 the NT57 with lead sealing was replaced by the **NT57D**, same specifications but with graded-glass seals. In the same year the **NT57T** was introduced, with thoriated-tungsten filaments which granted 18 A emission when operated at 9 V, 38 A, less than one half the power spent for the tungsten emitter of the NT57.

In 1939 at the Signal School F. M. Foley designed another silica triode which probably was the most powerful one of the family specifically developed for radar pulse operation. In the **NT 86** there are three tick hairpin filaments, each one terminating to two separate legs. Total filament current was 100 A at 10.5 V with an impressive emission of 90 A. Input and output stems were all moved near the circumference, at maximum distance from each other, so that the tube could safely withstand up to 50 kV anode voltage. In the Type 281 early warning radar two NT86s, pulsed at 28 kV, 60 A, generated 1 MW output pulses, 2 to 3 microseconds wide, at 90 MHz. The Type 281 radar set was still operative well after the end of the war.

Emilio Ciardiello for ase-museoedelpro

NT86 / CV1249

- 10.5 V at 100 A filamentary cathode
- 90 A total cathode emission
- 50 kV anode voltage
- 2 kW anode power dissipation
- 100 MHz max useful frequency

Note

Two NT86s at 28 kV, 60 A generated
1 MW out pulses, 2 microseconds wide

Fig. 5 - The NT86 high-power triode

Even if frequencies below 100 MHz were acceptable for ground and shipboard radar sets, for airborne use higher frequencies had to be preferred, in order to minimize the size and hence air drag of the antennas. In the mid 1930s, several countries were experimenting echoes obtainable using transmitters operating around 500 MHz, first with the Philips four-segment magnetrons proposed by Posthumus and then with the 'doorknob' triodes introduced by the Western Electric. In both cases anyway maximum power was limited to a few tens of watts, too low for most practical uses. Around the mid 1937 the British decided to operate their airborne AI radar at about 1.25 meters or 220 MHz. The pulse power of early prototypes, based upon a couple of 4304CB, was still low but in 1939 GEC introduced its E1046, the first 'micropup' VHF triode with external anode approved as **VT90**. A pair of VT90s gave 5 kW pulses at 220 MHz. Parallel experiments had demonstrated the need for higher power in early warning sets. Therefore the AMRE was anxious to have VHF triodes more powerful than the VT90 for the transmitter.

The file AVIA 7/715 refers to a VHF silica triode, probably an attempt to reduce the size of electrodes in a NT86-like electrode structure to operate at somewhat higher frequency. The tube, referred to as NT88, was still under development early in 1940. A variant, the 'Wireless XL', was proposed for operation down to 1.5 meters (200 MHz). From the little available information given in the documents, we know that its filament operated at 9 volts, 100 amperes. Presumably it was a scaled down execution of the three tick hairpins used the NT86. To ensure a good emission, the reduction of electrodes length was balanced by doubling the hairpin number, so to approximately retain the total emitting surface. We learn that its emission had been evaluated in 80 A. Anyway the graph in the last page of the file for a single NT88 shows an output power higher than 300 kW up to about 80 MHz and quite fast power decay above 100 MHz. Although the development of this tube was eventually abandoned, some samples of a **CV14**, believed to be the title reserved for NT88, still remain. No data can be found, since it was never released for production but the compact electrode assembly with six short and thick hairpins as emitter can be appreciated in the images below.

Fig. 7 - The experimental CV14 for VHF operation

Regardless of the severe frequency limitations of silica valves, mainly because of the generous tolerances of their hand-made manufacturing process, at the outbreak of WWII it was evident that the production of these tubes was by far too low for the wartime needs. GEC had been a pioneer offering power tubes with external anode, from its CAT transmitting tubes to the smaller Catkin types introduced in the 1930s. In these tubes the copper anode, sealed to the glass bulb by Housekeeper process, could easily transfer heat to any suitable external heat exchanger or radiator. Between 1938 and 1939 GEC introduced metal-glass power tubes for radar transmitters which would eventually replace silica valves with a few exceptions for Admiralty shipboard equipment. Metal-glass tubes quickly took advantage of the latest technological improvements. After that the Signal School in the late 1938 had run successful endurance tests of thoriated-tungsten filaments in the NT57, rather quickly from 1939 onwards metal-glass tubes were updated to the new emitters. Further improvements came from the use of oxide-coated indirectly heated cathodes, soon after the Megaw's successful trials of his **E1189 magnetron** in the summer of 1940.
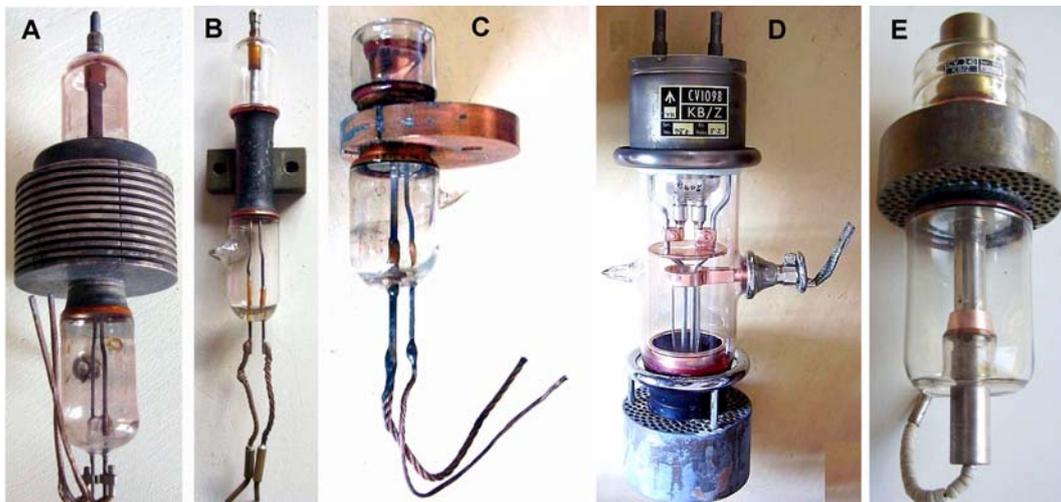

Fig. 7 - Metal-glass tranmitting triodes.

Some of the metal-glass tubes which would have replaced the silica valves. In 7.A we see the **VT90**, the first VHF 'micropup' triode introduced in 1939 by GEC as E1046. It could dissipate 100 W and operate up to 300 MHz. In 7.B a sample of the **CV15**, similar to the VT90, but conduction-cooled via a small copper block which replaces the finned anode radiator. In 7.C we see a milli-micropup sample, the **CV155** developed at GEC between the late 1939 and the mid 1940 under the code E1190. Fitted with oxide-coated cathode after the Megaw's experiments on the E1189

magnetron, it operated up to 1.300 MHz, two tubes in push-pull delivering 40 kW pulses. Among the high power tubes, the **CV1098** in 7.D, with thoriated-tungsten filament, was directly derved in 1939 from the E960 designed in 1938 at GEC by Le Rossignol. CV1098 could operate up to 250 MHz with anode voltage up to 23 kV. It replaced NT57T and was also used around 200 MHz in the AMES 2 ground radar, part of the CHL system. Its Canadian equivalent REL5 was used in the system installed to guard the Panama Canal. Although released quite later, in early 1944, the **CV240** in 7.E was the largest triode of the micropup family. Capable of operation at 15 kV with 125 A minimum emission, it could be used up to 100 MHz full ratings and up to 600 MHz at reduced ratings.

The collection includes some samples of silica valves, most of them of the types designed for the radiolocalization sets.

Go to the 'Silica valves exhibits'