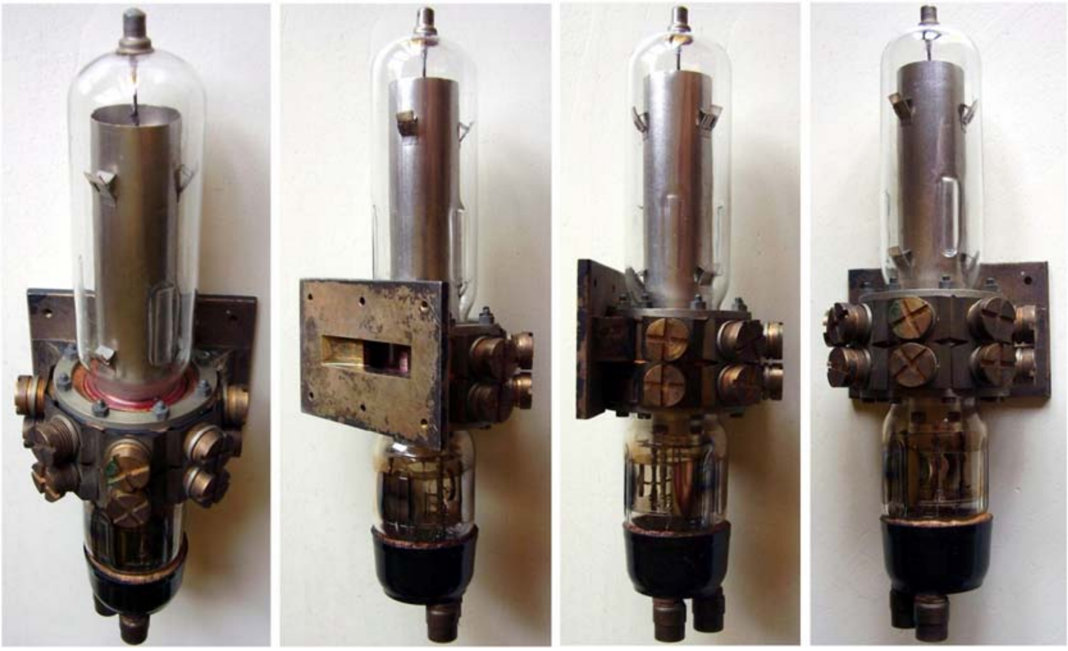
CV150 - Pulse Power Klystron, 1942



This rare sample of CV150 power klystron testifies the wartime development in England of the only microwave radar based upon pulsed klystron in the transmitter. The klystron, devised by the Varian brothers, was based upon the interaction of an electron beam with Hansen's rumbatron resonators. A continuously pumped prototype operated on the bench at the Stanford University since the late 1937. Its principle was announced in 1939 originating research for a possible use as power microwave source. In the U.S. Westinghouse and Sperry defined a couple of devices including the 10 W type **410** operating at 3 GHz. The same Professor Oliphant, who headed the laboratory at the Birmingham University where the prototype of multi-cavity power magnetron will be assembled in 1940, had visited Stanford in 1938. Klystron power sources had then been investigated at Birmingham, up to the development of the **9PK5 / CV109**, before the successful results of the GEC **E1189** magnetron. We know that from the Tizard Mission in the second half of 1940 both Britain and US for their microwave radar programs relied entirely on magnetron oscillators in the transmitter. Due to the difficulty of generating and keeping focused high-density electron beams, klystrons were confined to the receiving section, as low-power local oscillators.

Works on the H2S, a radar set specifically designed as airborne bombing aid and intended to be also used over Germany, started in England in November 1941. A variant of H2S based upon a high-power pulsed klystron was approved shortly later. The decision was taken for political rather than for technical reasons. Magnetron was considered one of the most valuable secrets, therefore no authority for flying any magnetron fitted radar over enemy lands was given, fearing that the secret could fall in enemy hands. On the contrary any captured radar set fitted with power klystron could not reveal secrets rather it would have address German future developments towards a presumable dead end.

EMI was asked to develop the klystron variant of H2S and, of course, the power klystron itself. The design specs of the klystron, frequency, power and dimensions, were presumably derived from data of the then available **CV38**, the very early unstrapped magnetron designed for airborne operation. In December 1941 a contract was placed with EMI Hayes to build 50 sets with modified transmitter. After the first trials of a prototype on an EMI coach, comparative tests started, using two Halifax bombers, one equipped with the standard H2S prototype and the second one with a klystron prototype. Unfortunately the entire EMI staff and the magnetron prototype went lost in June in the crash of the V9977 Halifax during a test flight. It was evident that even if 10 or 20 kW could be enough for an AI set to intercept an enemy airplane in air, higher power pulses were required to identify targets while flying over populated lands. On 15 July 1942 the development program for the klystron variant of H2S ceased and the test unit was removed from the second Halifax bomber. By the way when the order was cancelled more powerful strapped magnetrons as the **CV64** or the **CV192**, both used in H2S variants, were on the way to be delivered in volume.

EMI put together all the knowledge available at the time and an experienced design team leaded by the television pioneer A D Blumlein to do its job. The question remains whether CV150 was really designed to operate as reliable microwave power source rather than a well-done fake, working just enough to deceive German scientists. According to the diary of Ed Ginzton, Professor in Physics at Stanford and cofounder of Varian, the unique design of CV150 was very impressive for solutions and performances, anticipating the developments that would have appeared only years later. His notes, after a trip to Britain early in 1944, are reported in the historical background of the paper '***High-Power Klystrons: Theory and Practice at the Stanford Linear Accelerator Center***' by George Caryotakis. Those notes give us most of the little information today available about this valve and its performance.

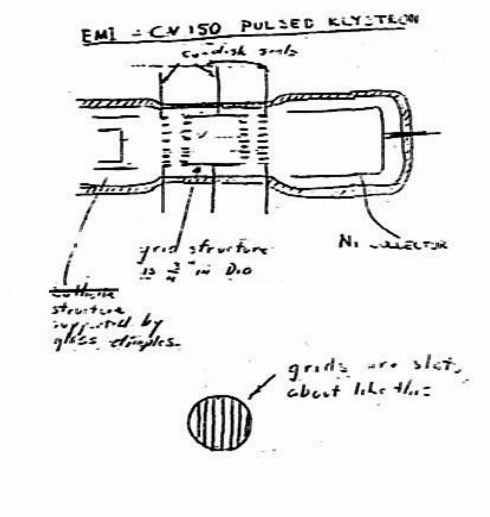
"…I saw a klystron of a remarkably simple design which produced 20,000 watts of power, well beyond any klystron made in the United States at that time. The fact that it was so simple and so beautiful impressed me enormously, and led me to develop a still bigger tube a few years later.

A two resonator klystron, using grids, and operating 12,000 volts has been designed and built for 9.1 cm. It was intended for an airborne system but due to changing circumstances will probably not be used. It differs from other pulsed klystrons developed in Britain in that it uses a very large beam cross-section, a very large current density and grids to improve the modulation coefficient of the gaps. Although the grids are large in diameter, the RF losses in these are made small by using large grid spacing. The effect of the latter are made small by the high acceleration voltage. As such, this tube represents the furthest deviation from standard klystron design that I have ever seen. The cathode focusing and/or grid interception losses are poor.

Only 50% of the current passes through the short, stubby channel and one would think that this should be much better. But in spite of this, the overall-efficiency at 12kV, and 150 kW input is 20%. This means that the actual efficiency is about 40%, that being the highest efficiency for a klystron that I have ever heard of. The tube uses a slot for coupling. It has a waveguide output, and it is tunable by means of plungers over 5%. The starting time is not larger than 0.1 – 0.2 microseconds. The tube is small, light, very easy to make, is easily tunable and can be used as a power amplifier. It is this tube that makes me think that the klystron may yet rival the magnetrons.

The life of the tube seems to be about 250 hours at present. It is thought that Ba is being evaporated from the cathode which finally ruins the tube. Experiments are now being conducted with lower cathode temperatures and longer life is indicated. The tube is now in preproduction stages... "

Ginzton also left drafts of the internal electrode arrangement and of the grid shapes.



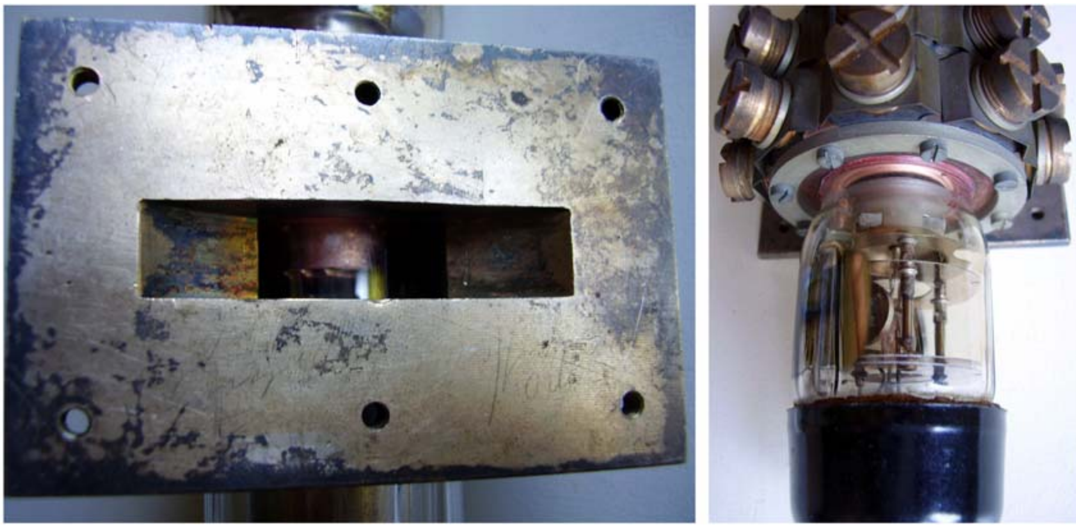
According to the notes of Ginzton and to those of Sir Bernard Lowell in his 'Echoes of War', data of CV150 can be summarized as follows:

- **Input pulses up to 12 kV at 12,5 A.**
- **Cathode emission in the order of 25 A.**
- **Output pulses up to 20 to 30 kW at 3188 MHz**
- **Up to 20% overall efficiency. Theoretical 40 % efficiency possible focusing the electron beam.**
- **Less than 0.2 µs build-up time of RF output pulses.**
- **Waveguide flange output. About 20 cm overall length.**
- **Lightweight, no need for heavy magnet to operate..**
- **13.0 V at 2.4 A heater**

These figures are even better than those specified for the early unstrapped magnetron for airborne applications, the E1198 standardized as **CV38**: 11.5 kV input pulses, 5 kW minimum and 8 kW typical output at 9.1 cm.

This unit is one of the very few samples built and still surviving today. EMI internal code of CV150 was PK150, where P and K presumably stay for 'Power Klystron' and 150 might well be the input power in kW.

In the images below some close-up views of the well spaced grid rods and of the cathode assembly.



- Left, the heavy and well-spaced rods of the second grid are visible from the output flange. Right, a close-up view of the large cathode.

Attempts were made to use the CV150 in other applications but none of the proposal went beyond the prototype phase. Probably ‘Lucero’, one of the systems of which today remain just a name, was a navigation system more or less similar to DME. We found the desectreted documentation of the blind bombing navigation system based upon CV150, the Oboe Mark IIB. Here is the airborne transmitter unit, **type T.R. 3539**, dated August 1943 and here are the **drafts of the TR and ATR cells**, CV157 and CV179, designed for this system. We know that Standard Oboe was a British rho-rho navigation system, quite similar to RCA **SHORAN** and operating around 300 MHz. A microwave version was attractive for the better precision it could offer.

References:

- **Edward Ginzton Papers (SC0330). Department of Special Collections and University Archives, Stanford University Libraries, Stanford, Calif**
- **Echoes of War, by Sir Bernard Lowell**
- **T.R.E. report T 1478**