10 – Cathode ray and imaging tubes

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Cathode-ray tubes or CRTs are special vacuum tubes capable of showing luminous traces where electrons impinge the front screen. Electrons, emitted by an electron gun, are focused in a sharp dot which strikes a thin layer of phosphors inside the viewing screen. Cathode-ray tubes were used as display units until the end of the past century in countless applicatios, mainly in television, computer and radar fields, but also in oscilloscopes and measurement sets, as well in communication equipment, teletype and FSK decoders or top class tuners.

The forerunner of known CRTs was the Brown tube, devised in 1898 and capable of generating a glowing fluorescence when high voltage, in the order of 50 kV, was applied between cathode and anode.

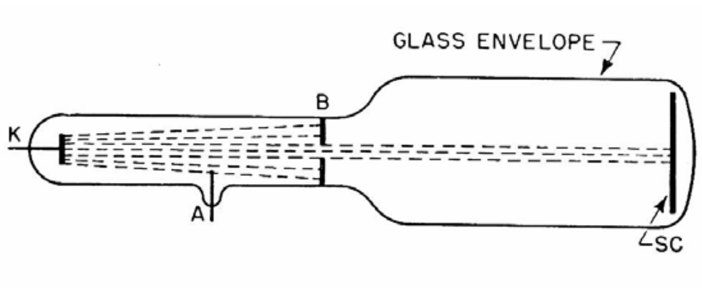

Fig. 1 - In the Brown tube the still unknown electron particles were extracted from the cathode surface by high voltage applied between anode A and the cathode K itself. High-speed electrons, directed to the center hole of the baffle B, hit the fluorescent screen SC, which returned a more or less faint glow.

In 1921 J. B. Johnson developed an improved type of tube which gave origin to modern cathode-ray tubes. The Johnson tube had several interesting features:

1. The filamentary cathode emitted plenty of electrons when hot, no need for high anode voltage.
2. Its accelerating electrodes, together with the addition of a small amount of argon gas in the envelope, made possible a sharp focusing of the spot on the screen.
3. The front viewing screen had a layer of fluorescent substances deposited on the inside surface of the glass bulb and the trace could be observed from outside.
4. The vertical and horizontal pairs of plates allowed to electrostatically deflect the spot over the screen surface.

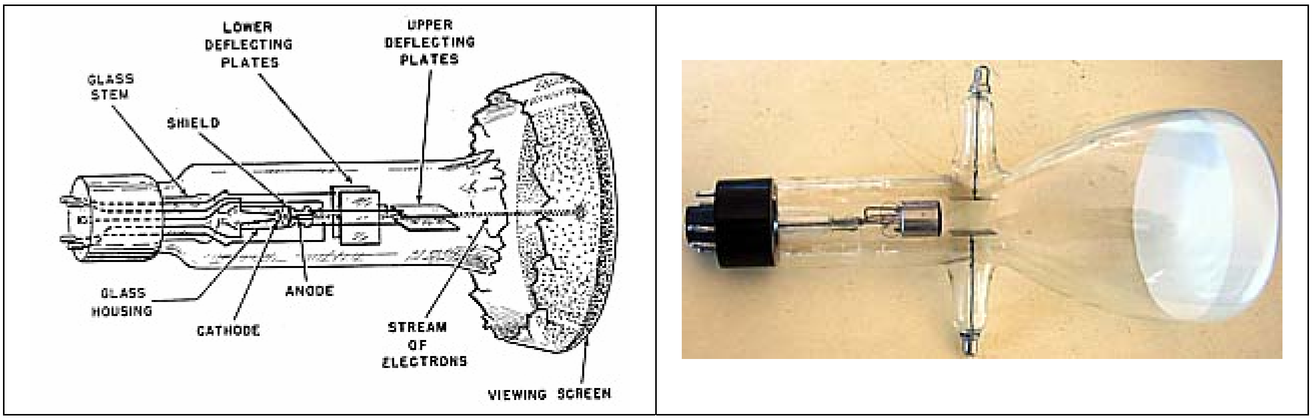

Fig. 2 - Left, drawing of the Johnson tube showing its electrode arrangement. Right, Narva BR-2 was a didactic cathode ray tube fitted with only a couple of deflection plates. (Click on each image to enlarge)

In the Johnson tube a small amount of argon gas was used to counteract the repelling actions inside the electron beam and help focusing of the spot on the screen. Anyway its basic electrode structure was adopted in all the subsequent electrostatic deflection types, commonly used in oscilloscope and in many indicator tubes for about eighty years.

In the thirties we see the first use of CRT tubes in early experimental television systems. Nevertheless the blast of WWII boosted its use for military in radar systems. The electrostatic deflection was retained only for small screens, up to five inches in diameter, with very limited deflection angles, otherwise the electron beam could interfere with the same deflection plates. Magnetic deflection was preferred to design more compact tubes with larger screens. Depending upon the application we see the same electrode assembly used in similar tubes which just differed from each other for the screen phosphor. Green, medium-persistence phosphor was used in oscillographic tubes, white phosphor was intended for television applications, blue, short or very short persistence types were used in photographic oscillography. A special screen, characterized by medium-short purplish-blue brightness followed by long yellowish-green phosphorescence and usually referred to as P7, was devised for radar applications. The collection includes several CRTs designed for both oscillographic and radar applications, some of them made during WWII.

Fig. 10.3 – Some of the CRTs in the collection, starting from WWII. Also included dual-beam, distributed deflection, and memory types.

After the war new markets opened for cathode ray tubes, including television sets, instrumentation and computers. Remarkable in this case is the use of racks full of CRTs as memory banks for computer mainframes in the early fifties. This kind of storage memory was devised by Williams and Kilburn at the University of Manchester in England around the end of the war. It exploited the charge built in the front screen of a CRT, in the region struck by electrons, to store dots or dashes, equivalent to logic states '0' and '1'. Here is the summary of an article from Electronics, December 1953, which shows a CRT storage system, 512 words by 45 bit, built at US National Bureau of Standards. Write or read speeds up to 21,000 words per second were possible. Each one of DACs used to drive the X and Y deflection plates of the 45 CRTs used three 807 beam power tubes in parallel.

The ability of dielectric materials to store charges when hit by electrons led to the development of storage tubes, capable of storing oscillographic or radar images for considerable time. One of the finest solution to prolong the storage time was the use of a second 'flood' cathode which supplied low-energy electrons over the entire memory screen, so refreshing the information written by the main electron beam. The first commercial storage oscilloscope was introduced in 1955 by Hughes and a sample of the 'Memotron' CRT is available in the collection.

Other cathode ray tubes were designed for high-speed oscilloscopes, capable of observing fast phaenomena. In these tubes vertical plates were replaced by distributed constants deflection arrays. Successive small plates were fed by a delay line. The capacitance of the deflection system was very low and the signal propagated from a segment to the next one synchronously with the electrons. Collection also includes cathode ray tubes capable of displaying waveforms in the order of hundreds of megahertz and even gigahertz, with sub-nanosecond risetime, as the Tektronix T581. The fastest ones, two T519P-11 exhibits, are inside the 519 oscilloscopes, one still operating with its sharp and brilliant blue trace.

Also in the collection are a demo unit of CRT tube, the BR2, and a very special CRT, designed to evaluate magnetic fields.

10.2 – Imaging and other special function

Fig. 10.4 – Some special function or imaging tubes, including an image orthicon, a character generator and a couple of image converters. A) 5820 was a high-sensitivity image orthicon. Here amplification of electrons emitted by the photocatode was performed by a multi-stage secondary emission structure. B) CK-1414 was an electronic character generator. An electron beam scans a mask containing etched characters before striking the plate, formed by a metal disc. A strobe window is activated in correspondence of the character to be displayed. C) 1P25 was an American IR image converter introduced in WWII. D) CV148 was one of the British IR image converters hastly designed by EMI in WWII. Emitting surface and the fluorescent anode are spaced a few millimeters from each other. Under strong electrostatic field electrons travel from cathode along lines perpendicular to its surface, to form an undistorted image on the screen. CV148 was powered by a Zamboni pile. (Click on the image to enlarge)

This section covers tubes designed to acquire images, converting them in electrical signals, or even tubes capable of converting images caught in a given IR spectrum in visible ones.

The first family of tubes is based upon a semitransparent cathode, scanned row by row by an electron beam. Electrons emitted by illuminated dots when stimulated by the beam are captured by the anode. In some tubes a secondary emission electron multiplier increases the sensitivity by a factor depending upon how many stages are between the photosensitive cathode and the anode.

Image converters have inside both a photocathode, sensitive to the wanted radiation spectrum, and a fluorescent screen. In their simplest form both surfaces are flat, facing to each other at a very small distance. Under the high voltage electrostatic field applied between the two metallized surfaces electrons emitted by illuminated cathode dots travel to the screen, where they form a visible image. In other cases these tubes can contain electrostatic lenses and even photomultipliers to resize and amplify the image focused on the photocathode by the optical system.

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- Last edited February 2016 by Emilio Ciardiello