9. Computer rated high-rel tubes, counters and indicators

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This section lists tube families designed for predictable operation and life, even in hostile environments, with special reference to tubes intended for applications in computers, data transmission systems and electronic counters or frequency meters.

The need for high-rel tubes was related in part to operation of electronic sets in hostile environmental conditions, such as extreme temperatures, acceleration or vibrations. But even the increasing complexity of electronic equipment, with the diffusion of computer aided operation in each task, was among the reasons for specifying more reliable tubes. Before WWII in a military aircraft electronics was almost exclusively limited to simple radio sets, averaging about five vacuum tubes each. After the war, just few years later, a bomber carried electronic equipment totaling about 250 vacuum tubes. This figure continued to rise in the years, even due to the introduction of computer controlled functions. In the early '50s small computers could use several hundreds of vacuum tubes.

It should be noted that most of early computers were analogic, based upon synchro resolvers, servo motors, potentiometers, differential transmission gears, mechanical cams and integrators. Often they included magnetic amplifiers, no need then for electron tubes or at best marginal applications as error amplifiers in servo loops. Analog computers solved almost any complex problem, up to missile guidance and interception of moving targets. In 1951 RCA built the **Typhoon**. With its 4.000 tubes, some 100 dials and 6.000 plug connection switchboard it was the largest analog computer ever made. Well, just considering the tubes and assuming a useful life of 1.000 hours for each of them, we should expect a failure every fifteen minutes or a mean time between failures (MTBF) of only 15 minutes. Too little even to run a single simulation! Even if average computers in the early fifties were by far more simple, the need for high reliability tubes was evident to the same tube manufacturers even before military and governative agencies made their acceptance standards more severe.

The analog interface was retained through the fifties even in many specialized digital computers. Conventional sensors still supplied analog voltages or currents for each physical magnitude, temperature, pressure, attitude, velocity, heading, acceleration, vibration and any other parameter. Unfortunately digital computers were in need of numeric values to operate, hence a relevant part of early flight computers, for instance, was dedicated to the acquisition of input parameters and to drive output actuators. Quite common was the use of specialized counters to totalize external events or even to drive multiplexer and demultiplexer circuits in data acquisition or in telemetry.

Even digital computers were quite different from modern ones, often based upon unusual solutions and components. To give a few examples, early storage memories could be steel tubes full of mercury, used as delay lines, or **racks full of cathode ray tubes**, each CRT used to store a thousand bits. Compact computers could use **fused quartz delay lines** as storage memory and only from the mid fifties ferrite core memory banks went in common use.

The development of high-rel tubes was then pushed by the increasing complexity of computers in miltary and even in civil applications. RCA introduced its '**Special Red**' family in 1948, probably due to the demand of its own people assigned to the Typhoon Project which was started just one year before, still based upon octal tubes. Around 1950 new designs moved to miniature and even subminiature tubes. Other tube manufacturers launched their own quality programs more or less in the same years. General Electric named it as '5-star', Sylvania introduced its 'Gold Brand' line, with golden writings, Westinghouse proposed its ‘Reliatron’ quality mark and Amperex (Philips) began to sell ‘PQ’ or ‘Premium Quality’ tubes, often with gold-plated pins.

Digital circuits gave origin to some families of tubes with specific properties. We find tubes, derived from standard types, redesigned for reliable operation in computer applications, most of the variants being related to heater power drain, life expectancy and recovery from prolonged cutoff.

Computer mainframes in the fifties could contain many hundreds or even thousands tubes. The power required by heaters was relevant and contributed to temperature increase of electronic components inside the cabinets. By Arrhenius law, high temperature contributed to shorten the life of components. Low heater current drain then helped to keep tubes and other components cooler, so increasing their life. Tubes with high efficiency cathode-heater assemblies were made available, compatibly with a stable emission through their life. Around the mid fifties Raytheon proposed the use of **filamentary subminiature tubes** in computer circuits for the lowest heater drain.

An important parameter to be controlled in tubes intended for computer application was the perveance, or the cathode emission capability. This beacause it was observed that ordinary tubes could develop an excessive interface resistance (between cathode and oxide layer) when operated at cutoff for a long period. The use of pure nickel cathode sleeves always granted plenty of electrons when resuming from cutoff at the cost of a more complex and expensive activation process.

Among the tubes used in computer techology we could list many types of which today even the memory is lost, as some binary adders, analog multipliers, digital to analog and analog to digital converters, memory CRTs, as well as simple gas diodes. The same logic state indicators, derived from tuning indicators and forerunners of vacuum fluorescent displays (VFD), were designed to be driven by digital circuits.

Due to the need of combining each tube family with its relevant application, this section is largely incomplete and still waiting for an ordered list of special applications and the related vacuum tubes. At the moment the only complete subsection is that dedicated to throcotron counter tubes.

9.2 – Trochotron counters

Many structures were devised by communication firms to replace electro-mechanical switches with faster electronic types in the transmission of signals by wire or by radio. One of the proposed structure was based upon a narrow electron beam driven by a rotating magnetic field, to sequentially impinge a couple of anodes out of a crown, placed all around the cathode. This lead to the development of quite fast multiplexer and demultiplexer tubes. The rotating magnetic field was generated by a couple of coils surrounding the tube, driven by a sequencer.

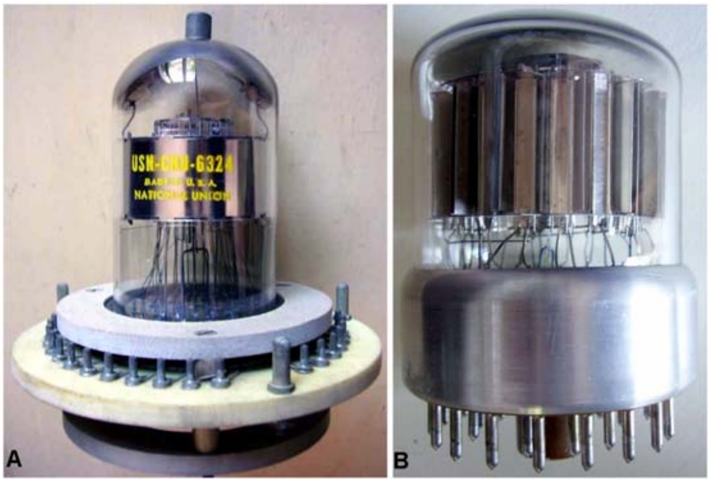

Fig. 9.1 – A) National Union 6324 was a beam switched 25-line multiplexer, with 25 control grids, as signal inputs, and a single anode from the top cap. It had to be operated inside a coil assembly which generated a step-by-step rotating magnetic field. B) 6090 was a 18-line decoder/demultiplexer, with a single control grid and 18 output anodes all around. (Click the image to enlarge)

Other structures were devised, capable of operating without the driver coils, inside a fixed magnetic field, the switching to the next electrode being accomplished pulsing the cathode. These structures were perfected by Saul Kuchinski at the Research Center of Burroughs in Paoli, PA, leading in 1955 to the introduction of the first commercial trochotron counter. A comprehensive description of magnetic beam switching tubes, also known as MBS or trochotrons, can be found **here**.

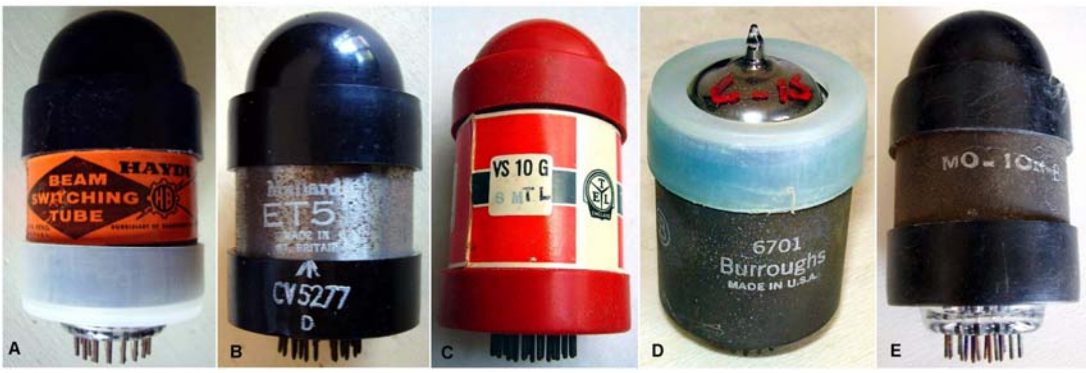

Fig. 9.2 – Samples of trochotron tubes. The early type, the HB-100 or MO-10, registered in June 1955 to Haydu as 6700, was also license built by Mullard and ETL. It was followed by the low voltage variant HB-101, registered as 6701, and later by the high-speed variant, the MO-10-R, registred as 6704. A) HB-100, also known as MO-10 or 6700, was the early commercial trochotron counter by Haydu Brothers, Tube Division of Burroughs. B) Philips built its own copy of 6700, coded as ET51. In the collection there are samples badged as Mullard and as Mazda. C) Also Ericsson made its own copy, the VS10G. D) 6701 was a low voltage variant, capable of operating at 20 V. It was intended for use in early solid state logic circuits. E) MO-10-R, also known as 6704, was rated for operation at over than 10 MHz. (Click the image to enlarge)

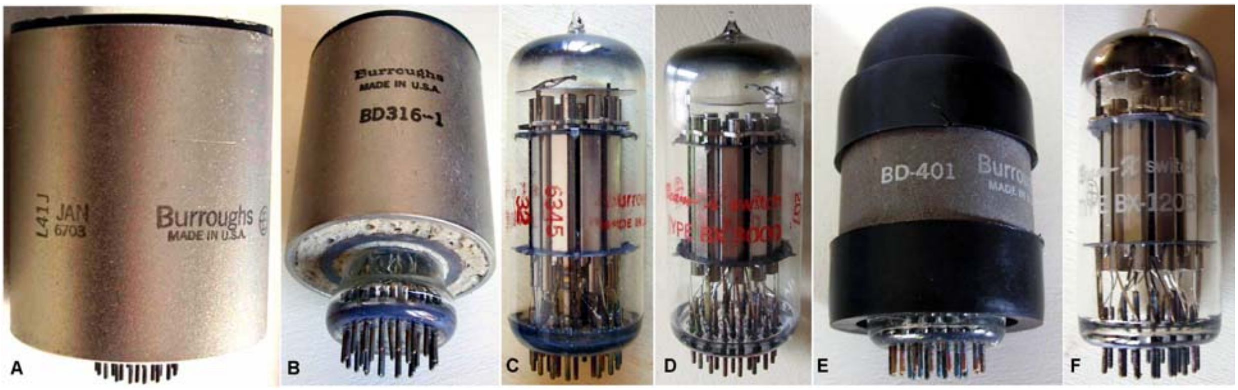

Fig. 9.3 - Other trochotron devices. A) BD301 / 6703 was a magnetically shielded variant of 6700. Magnetic shield was necessary when mounting more trochotrons side by side. Unfortunately it was bulky with its 2.25-inch diameter. B) Burroughs tried to reduce someway the size of its devices shrinking the glass bulb over the 27-pin base. The BD316-1 is the shielded version of this short lasting family. In the above photo are clearly visible, as in a section, the black ring of the magnet, the filler foam and the outer shield. C) In the Beam-X family the source of magnetic field was moved inside the glass bulb, using ten magnetic tiny rods which also were used as target electrodes. The size reduction was impressive. The BX1000 / 6710 was the first component of the family, replacing the 6700. D) BX3000 / 6712 was an high-power variant, with drive current raised from 2.7 to 5.0 mA. Usually nixie numeric indicator were driven by trochotrons when visual indication of the count was required. E) Even if the BD401 / 6702 was a trochotron, its design was specialized for use as noise source. F) BX1203 / 6713 was another tube designed as noise source. (Click the image to enlarge)

The collection also includes a couple of trochotron counters, listed in the instrumentation. One of them, the **FR-114/U frequency meter**, is fully working and complete with its technical manual.

Another kind of beam switching counter was the unique E1T made by Philips and related firms. In this tube the electron beam was deflected by electrostatic fields to one of ten stable positions. Even if E1T was not fast as trochotrons, it could give a direct indication of the reached count, by the glow on two horizontal phosphorescent bars.

Fig. 9.4 - A sample of Philips E1T beam switching counter with electrostatic deflection. The beam could jump sequentially on a zigzagging trajectory, lighting a dot in corrispondence of the reached count.

9.3 – Dekatron tubes

Dekatron is a trade mark for a cold cathode gas-filled counter. In low speed applications these tubes were usually preferred to throchotrons, because of their lower price and even because their intrinsic capability to directly display the count. The drawback of these tubes was the quite low switching speed, in the order of 100 KHz.

Fig. 9.5 – Samples of gas-filled counter tubes from various manufacturers. The small tube with flying wires in the middle is a gas trigger triode, used to drive counter electrodes.

9.4 - Numeric indicators, Inditron™, Nixie™, Pixie™ and other types

Many electronic counters and the same trochotrons asked for another tube to display the actual count, otherwise available as voltage or current levels through the circuit. One of the early indicator was the National Union Inditron™. The most known device was the Burroughs Nixie™, a sort of neon bulb with 10 separate cathodes, shaped as numerals from 0 to 9. Nixies were quite expensive and Haydu designed the Pixie™, to offer a cheaper indicator. In the Pixie pins formed ten short rods, used as cathodes and placed behind an anode mask with the ten digits cut near its circumference. Nixies survived the vacuum tube era and we find them in modern sets well in the sixties and in the early seventies, until replaced by LED, LCD and VFD displays.

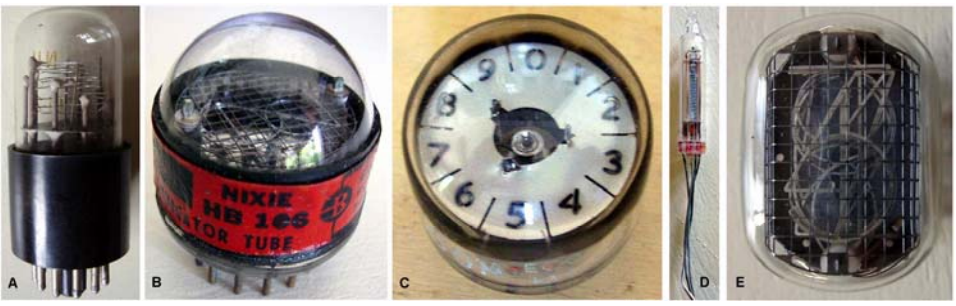

Fig. 9.6 – Samples of numeric indicators. A) GI-21 Inditron™ was among the early indicators. B) HB106 / 6844 was the early Nixie™, numeric display designed to interface trochotron counters. C) HB106 was followed by the cheaper Pixie™, here in a rare Amperex (Philips) version, Z550M. Amperex sold in America the (D) 6977 logic state indicator, equivalent to European DM160. Many computers used rows of such indicators which blinked to show the status of internal registers. E) A B5991 modern Nixie™ used in this HP 5245L counter.
(Click the image to enlarge)

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