THE STRANGE WORLD OF MEMORY TUBES

Eric Barbour

Intel did NOT originate the dynamic memory. Actually, some of the first memory devices used stored charges, much like today's DRAMs. Unlike DRAMs, this was done inside a vacuum tube by writing onto a non-conductive surface with an electron beam. This idea was pursued by numerous research labs after WW II.

WILLIAMS TUBES

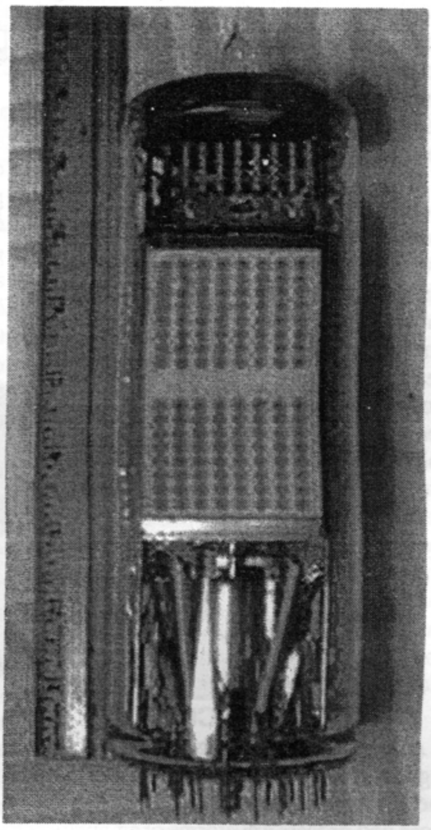
In 1946, Cambridge's F. C. Williams thought of using an ordinary CRT as a binary memory. By writing a spot on the CRT's face, a small packet of charge would be created there. It took some milliseconds for the packet to discharge, so by constantly refreshing the spot, it would be retained. The zero-or-one packet could be read back by pressing a metal pickup plate against the CRT's face, and amplifying the resulting weak pulse detected when the spot was refreshed. The whole assembly required the usual deflection circuits, plus staircase generators and high-gain amplifiers, plus plenty of mu-metal shielding around it to prevent external fields from ruining the weak electric charges.

Williams-tube memories were successfully used in the first two British digital computers, the EDSAC and the Manchester Mk. I. There was even a special CRT, with no screen phosphor, made for Williams use: the RCA 6571 of 1955.

The earliest memories for the Whirlwind computer used custom-made two-gun CRTs as Williams tubes, made by IBM's engineering shop and called IBM-85. Unfortunately, these tubes had reliability problems and were very costly to build, as well as having difficulty reaching the required goal of storing a 32 x 32 bit array. Whirlwind project director Jay Forrester tried to think of a more reliable memory device, so when he heard of the new ferrite magnetic materials, he though of using small doughnut-shaped cores of ferrite to store ones and zeroes as magnetism within the core. As soon as inexpensive core memory was developed, it rapidly replaced storage tubes, starting with Whirlwind in 1951.

RCA SELECTRON

RCA's much-feared leader, "General" David Sarnoff, wanted to jump into this computing stuff as soon as possible, and dominate it (or so he hoped). So he had RCA tube engineer Jan Rajchman design a charge-storage memory tube that would avoid the patentable features of the Williams tube. Development took place at RCA's new Princeton (NJ) Laboratories. The Institute for Advanced Study, also in Princeton, helped out with this project in order to evaluate the resulting memory devices for use in IAS-



256-bit Selectron

designed computers. When the Selectron was announced in 1949, the RCA public-relations department did its usual hyperactive job of spreading the word. As a result, publications of the period that barely mentioned the arrival of electronic computers gave the Selectron considerable play.

The Selectron looked like a giant 12AX7. Inside was an electron gun like that of a CRT, with an X-Y array of deflection plates. The beam impinged on a ceramic rectangle with 256 holes drilled in it. Each hole contained a small copper eyelet, of the type used on shoes for the lace holes. A charge was written on the eyelet, then read back and refreshed. Remarkably, it seems there were variations on this design. RCA even successfully built a 1024-bit and an amazing 4096-bit version. The latter used large cylindrical storage electrodes rather than a flat plate full of eyelets. Such a device would have been incredibly complex to manufacture, with hundreds of spot-welds to connect to the many selection electrodes.

This scheme had the same kinds of problems the Williams tube did, and was far more expensive to manufacture than a Williams memory, so the Selectron was not a success. The only major digital computer to use it was RAND Corporation's Johnniac of 1953. And Johnniac's designers had such problems with Selectrons that the machine was switched to core memory only 18 months after its completion. Ironically, RCA's own mainframe computers, such as the giant Bizmac, went to core memory as soon as it was available. The only other place where the Selectron found application was in an experimental digital memory for unknown application, built at the Air Force Cambridge Research Center in Massachusetts circa 1950.

RCA RADECHON

After the failure of digital memory using storage tubes, engineers realized that the charge-storage idea could be used to store and process waveforms of an analog nature. Note that this is quite different from the storage-tube display CRT, which used a special phosphor screen to keep an image visible for long periods of time.

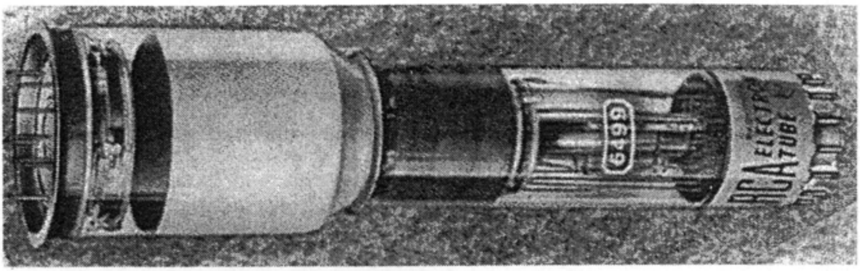
So, we have the "Radechon," which was apparently invented by Bell Labs engineers in 1952 (and not at RCA, as some think). Westinghouse was one of the first commercial factories to experiment with the Radechon design. Registered types included the 7225 and 7566, and Westinghouse also made special versions WX-4052, WX-4064, and WX-4065. Westinghouse didn't seem to utilize the idea very quickly.

The previous failure of the Selectron didn't faze Sarnoff and his men. They went back to the lab and came out with their 6499 Radechon in 1956 -- they exploited the Bell design faster than Westinghouse did. The 6499 had a double-ended construction, with a CRT gun pointing at a special target.

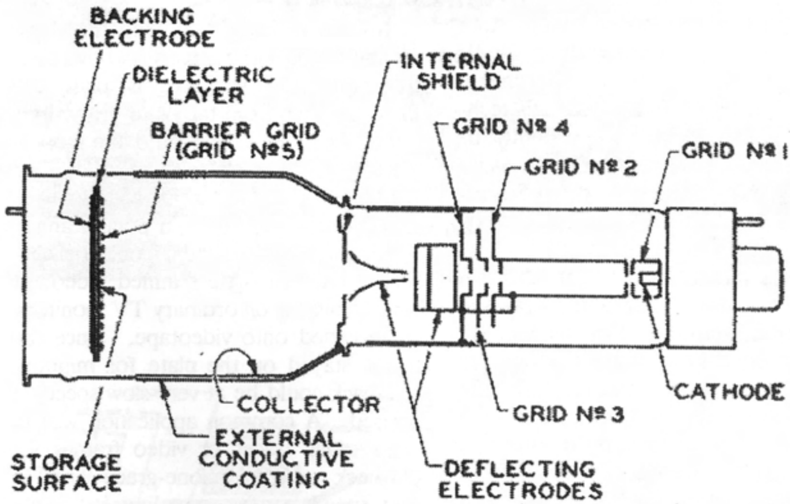
By firing the beam at a flat plane of dielectric material, a charge could be stored. A second beam pulse caused secondary electrons to cascade from the target, which would be scooped up by a surrounding collector electrode. A "barrier grid" helped push the secondary electrons away from the target and divided it up into squares. The voltage difference between the barrier grid, and a backing electrode behind the target, is then proportional to the amount of charge written at that square.

The best part of this scheme: instead of storing only zeroes or ones, the Radechon could store different levels of charge. So, it was usable as an analog memory was well as a digital one. It, like the Williams memory, required heavy shielding and complex driving electronics. Any arbitrary shape could be written on the electrostatic plate, then read back by the collector. And the plate could retain the charge for minutes or even hours.

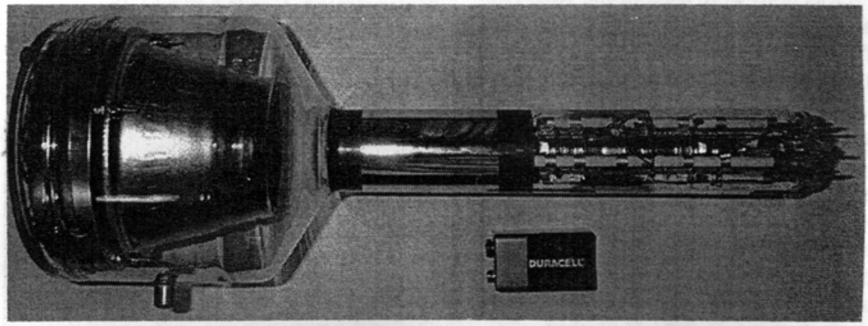
RCA also made the 6500 Radechon, a version with lower "discharge characteristics" specifically optimized for digital memory use. While the 6499 destroyed



6499 Radechon



Schematic arrangement of 6499



Soviet IN-12 storage tube

its charge memory during readout, the 6500 could be read many times before the charges had to be refreshed. All such RCA exotic tubes were believed to be manufactured at RCA's Lancaster, PA industrial-tube factory.

Raytheon also had their own version of the Radechon design, called QK357. Later versions were the 6835 / QK464A, CK7570 / QK411A, and CK7571 / QK685. It is amusing to read Raytheon promotional material all these years later -- in a 1963 article in *Electronics World*, they claim that the charge-storage tube was "discovered at Raytheon Co. by Dr. R. C. Hergenrother and Mr. B. C. Gardner in 1948." Yet by all indications, this technique was developed independently by several laboratories around the same time. One TCA member has a Soviet-made tube coded IN-12. It appears to be very Radechon-like in construction.

A device with an operating mechanism similar to the Radechon was the "Memotron," introduced by the Swedish telecommunications firm Ericsson in 1955. It was smaller than a CRT and used a cylindrical structure instead of a flat plate to store a 20-bit binary number. The Memotron was intended to perform the function of a crossbar switch in a telephone relay system. Since it had 20 separate output electrodes, it acted as a demultiplexer as well as a memory.

Radechons were used in the Rice University Model 1 experimental computer of 1958 for main digital memory, as well as in early video frame memories used for scan conversion. Amusingly, the Radechon's data sheet does not really address the exact number of charge packets that could be stored; imperfections reduced the usable area, and the tube had to be handled base-down at all times to keep internal debris from damaging the target. And as usual, core memory became more reliable and less expensive than these specialized tubes, replacing them very quickly for digital applications.

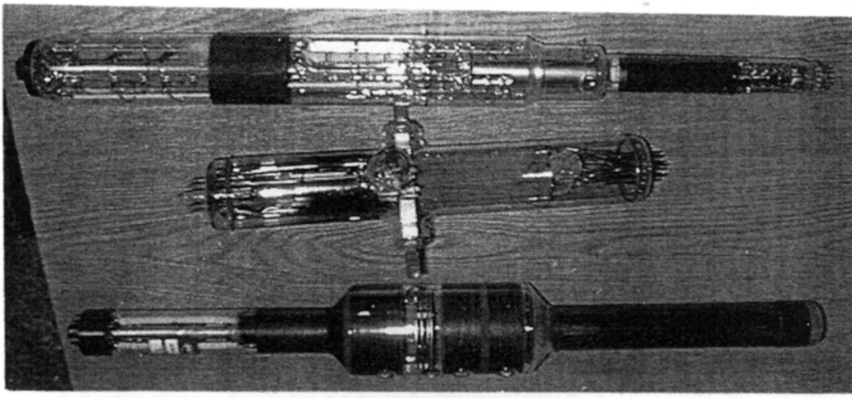
GRAPHECONS AND THEIR KIN

The Radechon concept was used in a variety of storage tubes, most of them quite obscure. They saw industrial and military use until the early 1970s. A variation of Radechon-like design was seen in a number of double-ended storage tubes for use in military radar or video equipment for image amplification or storage, and in television scan converters. Double-ended storage tubes were "invented" at several places during the same 1948-52 time frame. Raytheon, Hughes, Convair, Federal Telephone, and many others developed their own versions.

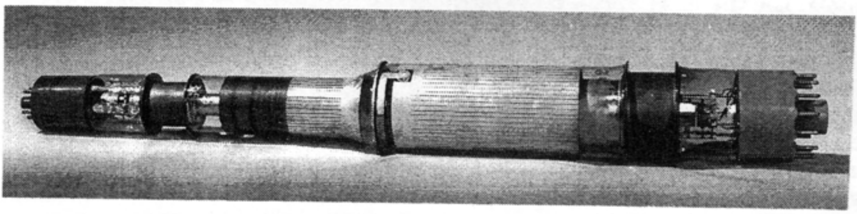
Instead of being read with the single writing beam, Graphecons had two electron guns. One wrote to the plate, and the other read from the plate. By writing a video or PPI image onto the storage plate, it was possible to store it and then read it back at a different vertical / horizontal scan rate. Thus, a polar-scanned PPI display from a radar could be converted into TV-style scanned video for remote display on ordinary TV monitors, or recorded onto videotape. Since the image stayed on the plate for minutes, readback could be at very slow speeds if desired. A common application was to store radar traces or video frames for playback over telephone-grade lines at slow speeds, or for recording onto magnetic tape -- in a manner similar to facsimile transmission.

In 1965, Westinghouse engineers demonstrated a video player that used vinyl phonograph records to store video. The "Phonovid" used a scan converter tube to convert slow-scanned video played from the disk into regular video for display on a TV set. There was no word on the resolution or reliability of this design -- like many pre-1970 "home video" devices, it was apparently not commercialized. Westinghouse scan-converter tubes included types WX-4640, WX-4821, and WX-30064.

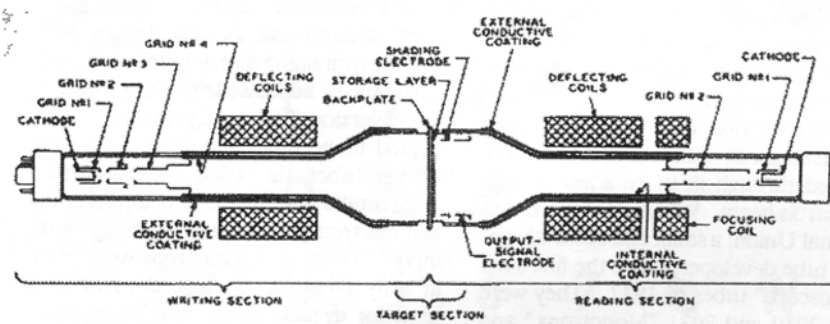
Early types, among the few to be mass-produced, were the RCA "Graphecon" types 1855 / 6896 (1958) and 7539 (1960). They saw use in commercial video scan converters. Raytheon was a major man-



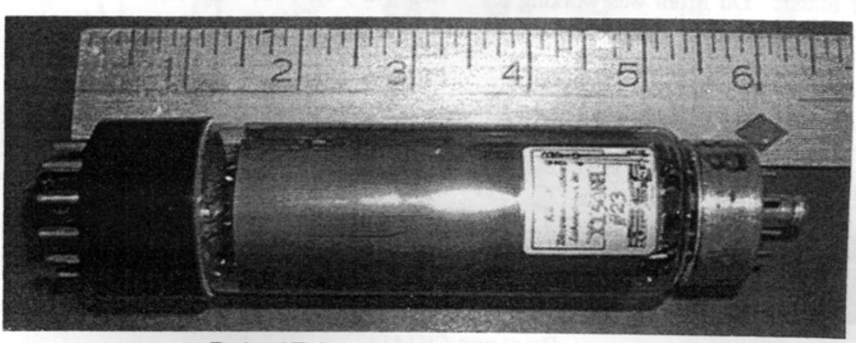
A collection of double-ended storage tubes



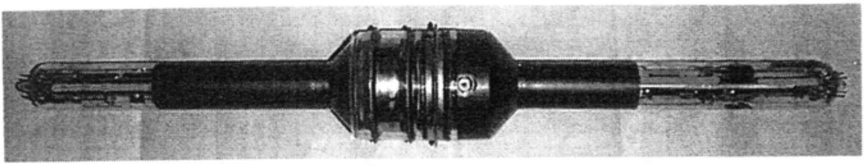
RCA 1855 Graphecon



Schematic arrangement of 7539



Federal Telecommunications Labs X150NH



Thomson TMA406H

ufacturer of double-ended storage tubes. They included CK1383, CK7572 / QK703, CK7575 / QK787, 7702 and 8602. Most were about 24 inches long, except the obscure ML602, which claimed similar 1000-line video resolution in a 12-inch-long envelope. Rauland was also a major manufacturer of storage tubes, including types 6233, 6253 and 8098. Federal Telephone made special versions for military customers, such as the X150NH, whose application remains obscure to this day. And in Europe, Thomson made scan-converter storage tubes. Their TMA406H was a close copy of the RCA Graphecon design.

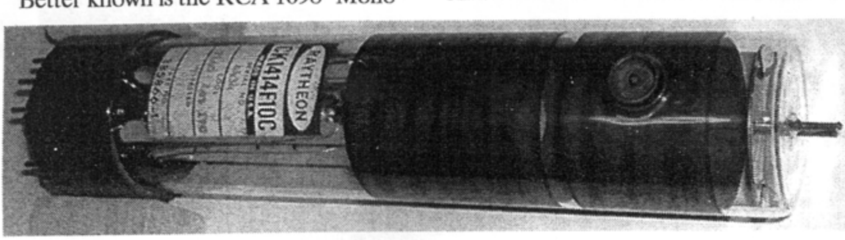
OTHER DEVICES

Because they tended to be experimental or for low production, very few storage tubes were documented in tube manuals, announced to the industry, or even assigned EIA type numbers.

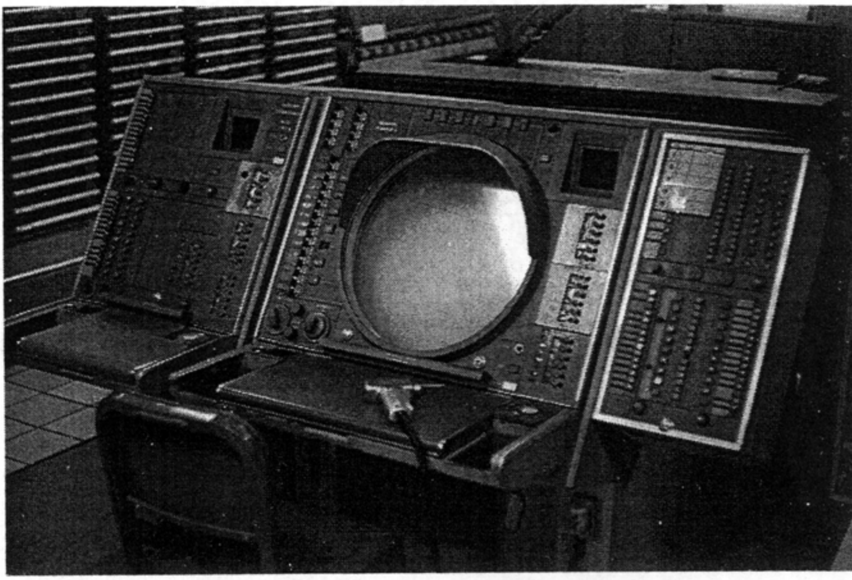
Another storage-tube scheme added a thin metal mask with letters and figures punched through it, to be scanned with an electron beam. We have evidence that National Union, a small and relatively obscure tube developer, made the first such "Monoscope" tubes in 1937. They were called 2030 and 2031 "Monotrons," and apparently had simple TV test patterns in their masks. Du Mont was working on similar devices, called "Phasmajectors," in 1938.

Better known is the RCA 1698 "Monoscope" tube of 1945. The mask in a 1698 had only numbers 0-9 and a few simple graphic characters. Later monoscope tubes had complex TV test patterns stamped in their masks. While storage tubes were akin to RAM memory chips, monoscopes were equivalent to ROM memory.

A more complex monoscope tube was the "Charactron" (Convair and M U Inc., 1952), intended for addition of alphanumeric data to television images and for early computer CRT displays. Convair's electronic division later became part of Stromberg-Carlson. Raytheon, Hughes, Federal Telephone, RCA, M U Inc., and other firms built Charactrons under various type numbers. Raytheon called their version the CK1414 "Symbolray." Some were monoscope-type designs, with a mask containing alphanumeric symbols that could be addressed in an X-Y fashion. Large versions had display screens . . . and tended to be huge and costly. As with storage tubes, they used a mishmash of electrostatic and magnetic beam steering and electron-gun designs, differing from model to model. Charactrons were used in early computer-controlled radar systems for display, most notably the giant SAGE ("Semi-Automatic Ground Environment") systems, with their direction displays being 19" Charactrons with long-persistence phosphor, made by Hughes. Charactrons are believed to have been of-

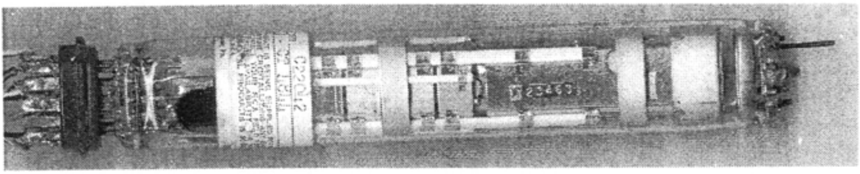


Raytheon CK1414



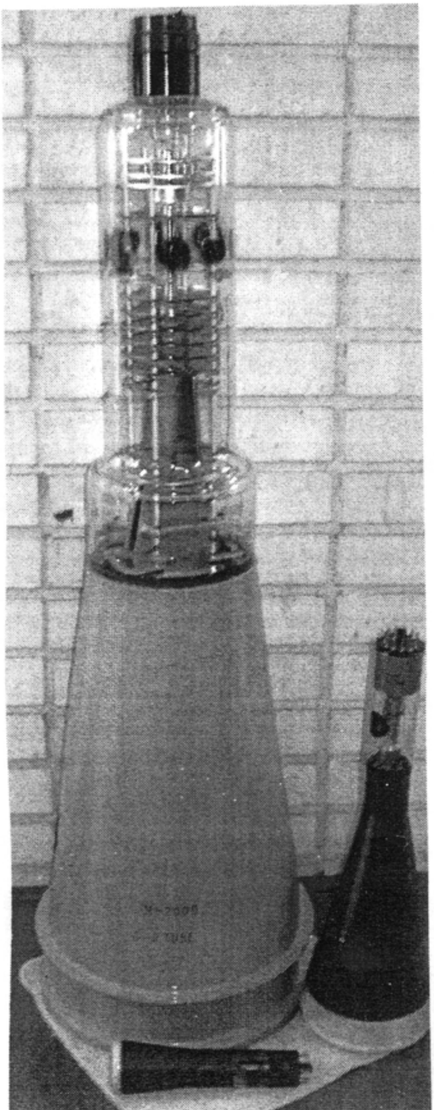
SAGE console with Charactron

Character set of Hughes 6577



RCA C22042 Alphechon

fered by Sperry-Univac as console displays for their 1106 / 1107 series main-



TW-1000, AKA M-2000, CRT

frames, as well as in microfilm-recording equipment made by various firms (most notably the Stromberg-Carlson 4020).

A tube that combined character generation with a CRT display screen was the Hughes Typotron (1964). Two versions are known, the H-1033 and the 6577. They were essentially identical except for the character masks. These enormously long and complex display tubes used a storage CRT faceplate plus two independent sets of deflection electrodes to focus the beam, scan it to the mask character desired, refocus it, then scan it onto the screen location desired.

Finally, in 1968 RCA's Lancaster factory produced a tiny memory tube specifically for the CRT alphanumeric display terminals that came with their Spectra 70 mainframe-computer product line. The Alphechon tube, which came in two types (C22042 and C22017A), served as the frame memory for the terminal's TV-style raster memory. This tube is extremely rare, as it was used only in RCA's terminals. RCA got out of the computer business entirely in 1971. All the Spectra 70 equipment was believed scrapped.

Even more obscure was a 37-inch-long CRT, the TW2000, built by AT&T for use in a complex digital memory system. It was for long-term offline storage, and wrote-to / read-from microfilm using a flying-spot scanner technique. This also required a liquid handling system for the developer and fixative, to process the exposed film.

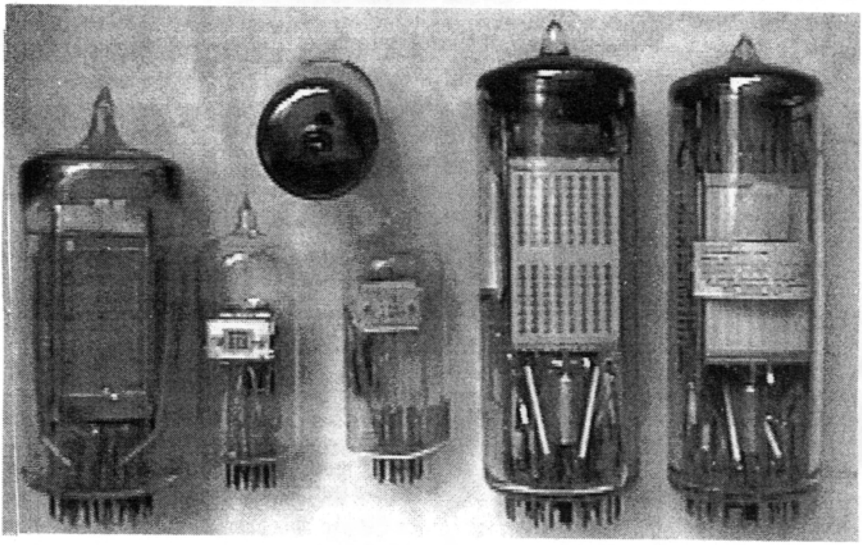
It is also believed that National Union was working intensively on memory-storage tubes, as articles appeared in 1950s electronics magazines which mentioned their work. However, there is little evidence that National Union successfully

Continued on p. 29

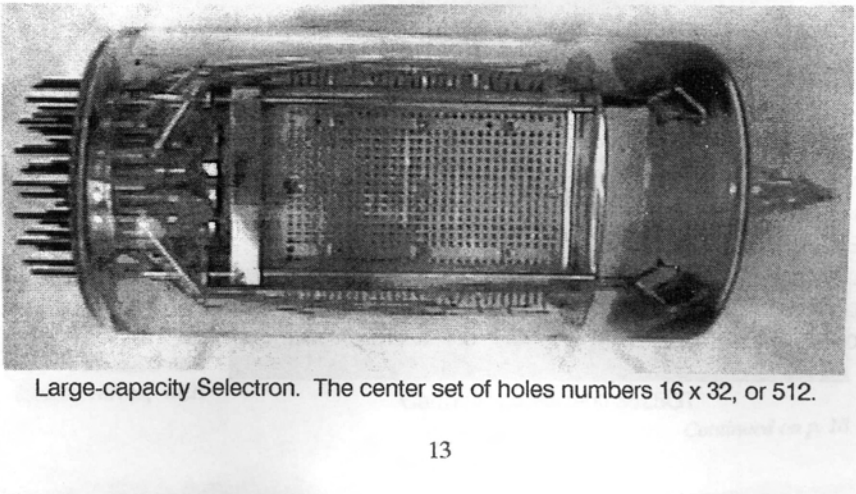
MORE ON THE SELECTRON

From resources provided by **Jerry Vanicek**

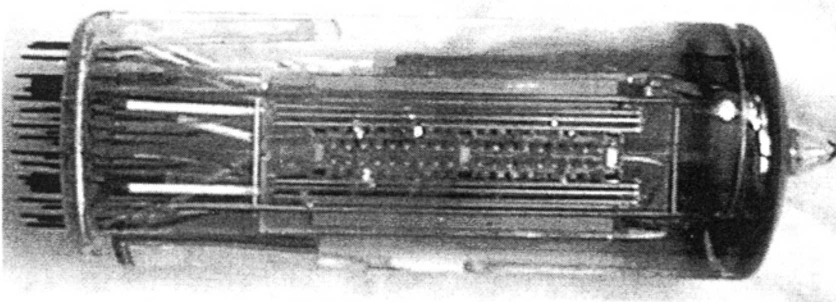
The Selectron storage tube is described in a comprehensive paper by Jan Rajchman, "The Selective Electrostatic Storage Tube," in the *RCA Review* for March 1951. The version presented there is the C7761 256-bit model. The device is covered in Rajchman's U. S. Patent 2,494,670 of Jan. 1950, "Electronic Discharge Device." (Clarence Tuska of early amateur-radio fame was RCA's patent attorney on this action.) RCA was doing extensive development on digital devices at the time; Richard Snyder and Rajchman had received a patent in 1947 on a binary adder-multiplier in electron-tube form.



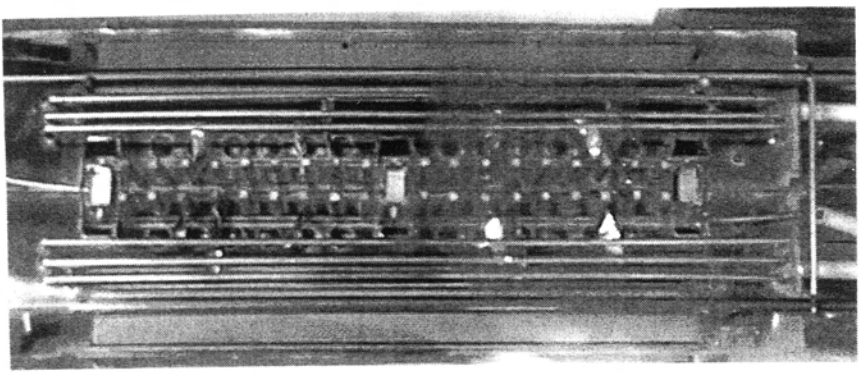
Group of six Selectrons. From left to right, Tube 1 is a high-capacity unit. Tubes 2, 3, and 4 are six-bit versions with single-sided arrays. The array in the upper tube is positioned horizontally. Machined targets are visible in the small tube at the right. Tube 5 is a laboratory model. The paper label visible on its left side is hand-written "Selectron / Rajchman." Tube 6 is one of the tubes used in the JOHNNIAC.



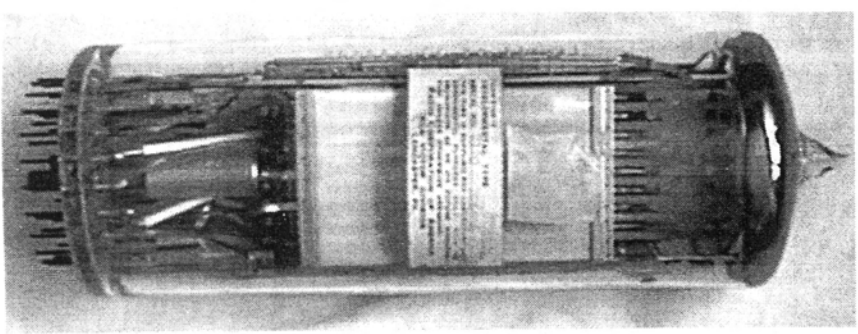
Large-capacity Selectron. The center set of holes numbers 16 x 32, or 512.



Side view of laboratory model.



Closeup of lab model showing the horizontal bars.



One of the tubes used in the JOHNNIAC. A bit of masking tape above the label has "O. K. / 12-2-58 / F. M." The label is the standard RCA "FORM F1657A / DEVELOPMENTAL TYPE C7761A / SERIAL NO. U120 DT6556 / THIS TUBE IS SUPPLIED FOR LABORATORY AND EXPERIMENTAL PURPOSES ONLY, WITH NO OBLIGATIONS AS TO ITS FUTURE MANUFACTURE UNLESS OTHERWISE ARRANGED. / RADIO CORPORATION OF AMERICA / RCA VICTOR DIVISION / LANCASTER, PA.