TEKTRONIX CRT HISTORY

Part 1. The Early Years

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Until 1954, Tektronix purchased all of its CRTs from three major OEM suppliers - RCA, Du Mont, and Sylvania. These were off-the-shelf, RMA-registered tubes. Of course, all of these were given their own Tektronix part numbers which were used for in-plant inventory control and replacement part ordering by customers. This first article will describe the purchased CRTs, their numbering, and usage in the early Tektronix oscilloscope models. This period of time extended from 1947 into the mid-1950s for most purchased CRTs and, in one case, the mid-1960s.

THE 5CP-A

The venerable curved-face 5CP1-A was the standard CRT installed in the 511 oscilloscopes which were introduced in 1947. The 511 was the first Tektronix oscilloscope and was a result of Howard Vollum's World War II experience in radar. He saw a great need for an oscilloscope with precision measurement capability for post-war research in the expanding fields of radar, television, nucleonics, medicine, and electronics. The widely used Du Mont oscilloscopes ("oscillographs" in Du Mont terminology) and CRTs of the 1930s and 1940s were somewhat lacking in this ability.

The 5CP1-A used in the original 511 continued to be standard in the improved model 511A oscilloscopes up through serial number 5099. It was also supplied in the model 514D introduced in 1950 up to the about 1953, when the 514-AD was introduced. According to one EIA (formerly RMA) list, the 5CP1 (Figure 1) was registered by the RMA JTC-6 CRT Committee in 1942. The sponsor was reported in another EIA list as RCA. Although the original data sheet used for registration was typewritten and the outline drawing hand drawn, this appears very likely. Later CRT registrations used manufacturers' preliminary data sheets and listed the manufacturer rather than the committee registering it. The 5CP7 data sheet registered at the same time is marked "Government Restricted" due to its wartime use of P7 phosphor for radar. The improved 5CP1-A having a "zero focus current" electron gun was registered by RCA in 1945. As a point of interest, I reviewed the updated 5CP1-A/5CP1-B/5CP12 MIL specifications (MIL-PRF-1/273J) in 1998 for the Department of

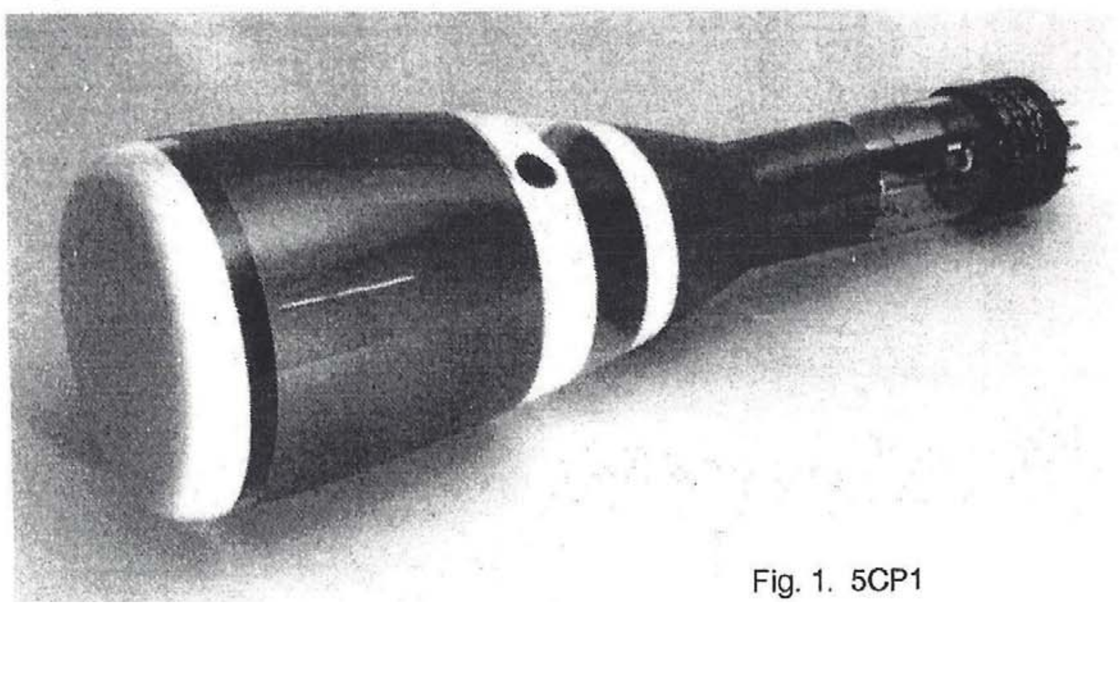


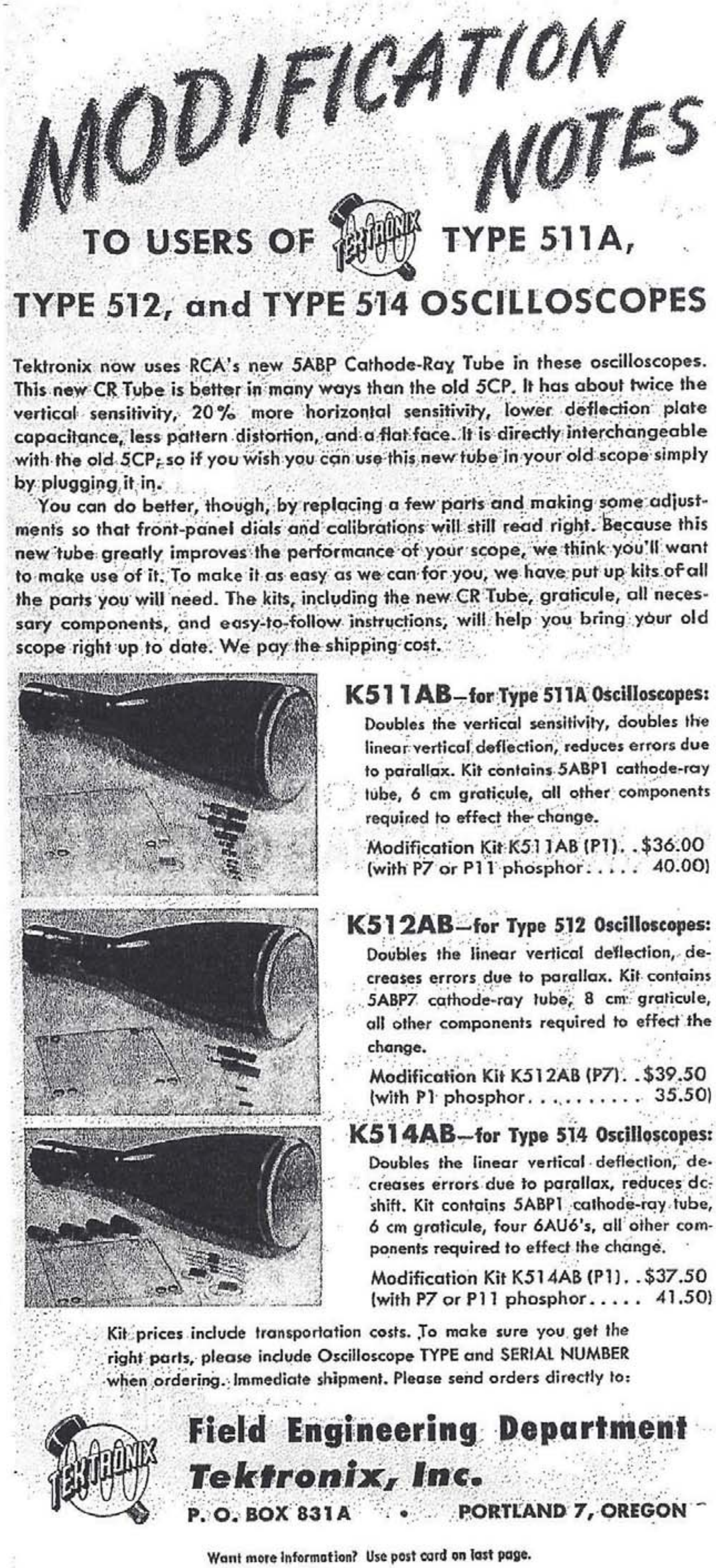
Fig. 1. 5CP1

Defense, and it is presumably still an active tube type, since no change notice has been received to move it to inactive status in the mean time.

The 5CP1-A was purchased only from RCA, according to surviving Tektronix records, although most CRT manufacturers included it in their product lines at that time. Instruments with long-persistence P7 and short-persistence P11 phosphors were also available on special order. The CRTs supplied in them were the RCA 5CP7-A and 5CP11-A. The model 512, introduced in 1949, used the long-persistence 5CP7-A as standard through s/n 2524, with P1 and P11 available as options.

THE 5ABP-

In 1952, RCA introduced the 5ABP1 CRT, which was very similar to the 5CP1-A except that it had a flat face to reduce measurement error due to parallax with the external plastic graticules in use at that time. It also had approximately double the vertical deflection sensitivity. This reduced the vertical amplifier gain required and made it easier to achieve instrument bandwidth specifications. P7 and P11 phosphors were



Advertisement, *Electronics*, Jan. 1954

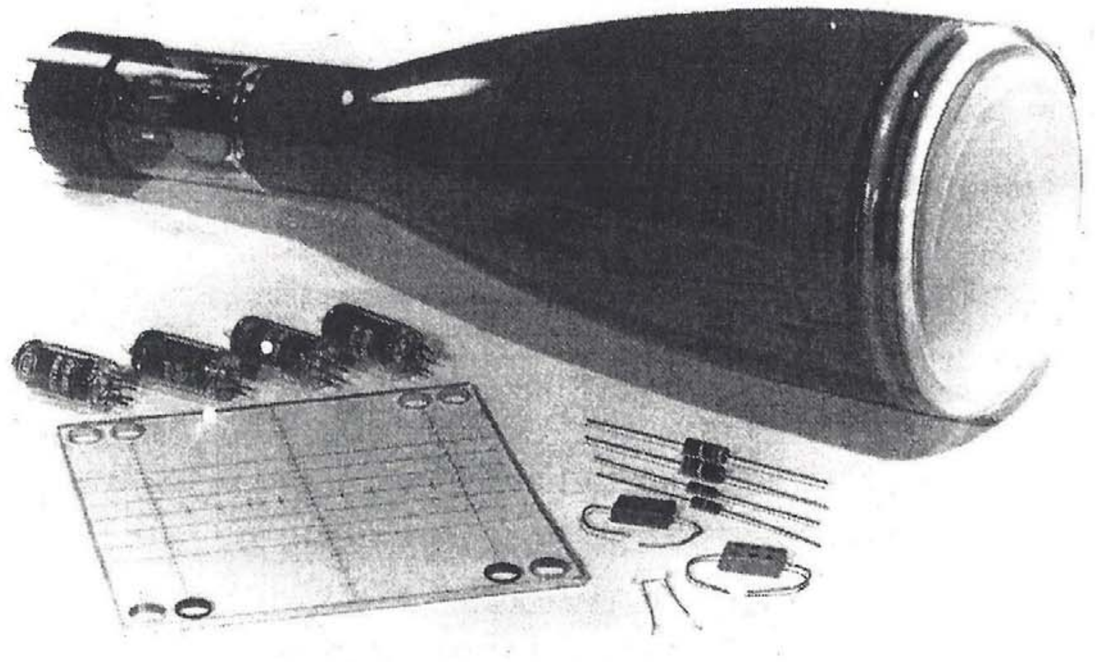


Fig. 2. Modification kit for 514, close-up

also available using the 5ABP7 and 5ABP11. Tektronix quickly changed to the improved tube for the models 511A, 512, and the new 514AD. Modification kits (Figure 2) were produced to upgrade older instruments. Other parts were included in the kits, such as a new graticule, resistors, capacitors, inductors, and even four 6AU6s for the vertical amplifier in the case of the kit for the 514.

In 1953 Tektronix introduced its first oscilloscope, the 524-D, devoted exclusively to television measurements. This instrument also used the 5ABP1 as the standard CRT. P7 and P11 were available as optional choices.

THE 5XP-

Another OEM 5-inch CRT purchased by Tektronix starting in 1950 was the Du Mont 5XP- series of high-performance CRTs (Figure 3), used in early model 513 oscilloscopes through serial number 1887 and in the model 517. This tube, registered with RMA by Du Mont in 1948, operated at very high accelerating voltage, 12 kV in the 513 and 24 kV in the 517, for high brightness, and was capable of displaying high-speed transients. With its approximately 50 MHz bandwidth, the 517 was pretty much state-of-the-art for its time. The CRTs were available in three versions; the 5XP1 (for general purpose applications), 5XP2 (for longer persistence), and the 5XP11 (for photo-recording of fast events). The 517 was catalogued with the 5XP11 as standard according to the 1952 Tektronix catalog with P1 and P2 optional. The 5XP2 was shipped as standard in the 513 with P1 and P11 being optional, according to the

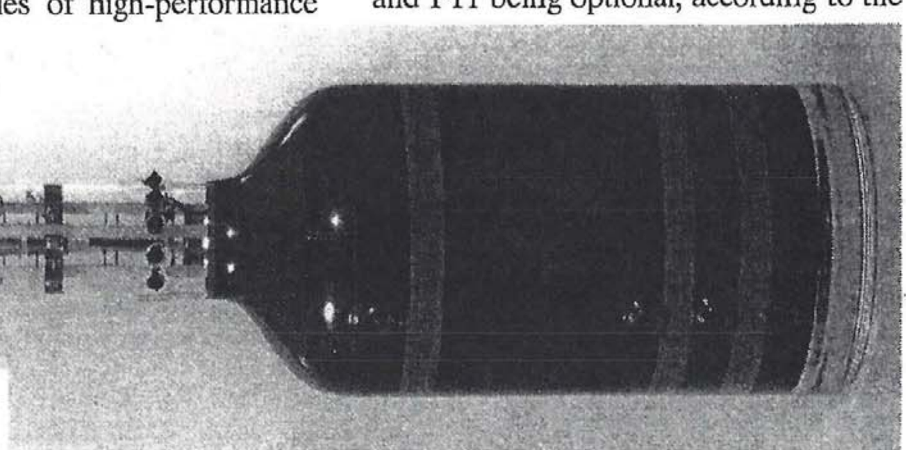


Fig. 3. 5XP2

same catalog. The 1950 catalog just lists all three as available in the 513 without specifying what is standard. Conflicting information exists in the May 1967 Cathode-Ray Tube by Instrument cross reference list. It lists the 5XP1-B, 5XP2-B, and 5XP11-MB under the above part numbers. Since the "B": version, which has a metalized screen, was registered with RTMA (formerly RMA) by Du Mont in December of 1952, it couldn't have been used in the early instruments. Probably it was added under the old p/n after that date to provide improved performance.

The 5XP- was a major factor influencing the decision by Tektronix to design and manufacture its own CRTs. Due to difficulty meeting instrument specifications, a comparison was made of tubes received through the company's regular purchasing channels and some acquired anonymously. It was found that Du Mont, a major oscilloscope competitor and the principal manufacturer of high-performance CRTs, was shipping their marginal CRTs to that upstart, Tektronix, in an apparent effort to maintain the Du Mont lead (at that time) in oscilloscopes. A similar situation existed with CRTs purchased from RCA, which also manufactured oscilloscopes. These problems resulted in a major and strenuous effort by Tektronix to begin manufacturing for its own use. Ultimately, it led to many significant advances in CRT design by Tektronix that led to the eventual end of Du Mont as a major player in the oscilloscope game. Du Mont struggled along for several years and was acquired by Fairchild in the early 1960s. They were never able to regain market share and it was Hewlett-Packard that eventually gave Tektronix some competition in the 1960s and 1970s. This wasn't all bad, as it kept Tek from becoming complacent after its early successes.

THE 3WP-

The remaining purchased CRT, the 3-inch flat-face monoaccelerator 3WP- (Figure 4), was undoubtedly used in far greater quantities by Tektronix beginning in 1954 and for much longer than any other of the others previously described. This was in spite of the fact that Tektronix was an established CRT manufacturer in its own right by then. The 3WP- was used in four versions; the 3WP1, 3WP2, 3WP7, and 3WP1. By the mid-1950s, the wide range of linear time-base sweeps demanded use of a longer persistence phosphor than that of the P1 phosphor previously used in most oscilloscopes. P2 permitted the full benefits of the slower sweep speed portion of the range. It is fairly efficient with good brightness, fairly long persistence at least in subdued light, and good resistance to burning at slow sweep speeds. Its green color is also a good match to the maximum sensitivity of the human eye. The 3WP2 became the standard CRT in the model 310 announced in 1955, 310A of 1959 (up to s/n 17372), model 315D of 1953 and model 360 of 1955 (up to s/n 2576) instruments. The 3WP2 remained standard until about 1964 when Tektronix had caught up enough on high-performance CRT designs to introduce a similar tube of its own, the T310-P2. The 3WP- is a pretty basic tube as CRTs go so the priority to convert from OEM tubes was low. The handy-

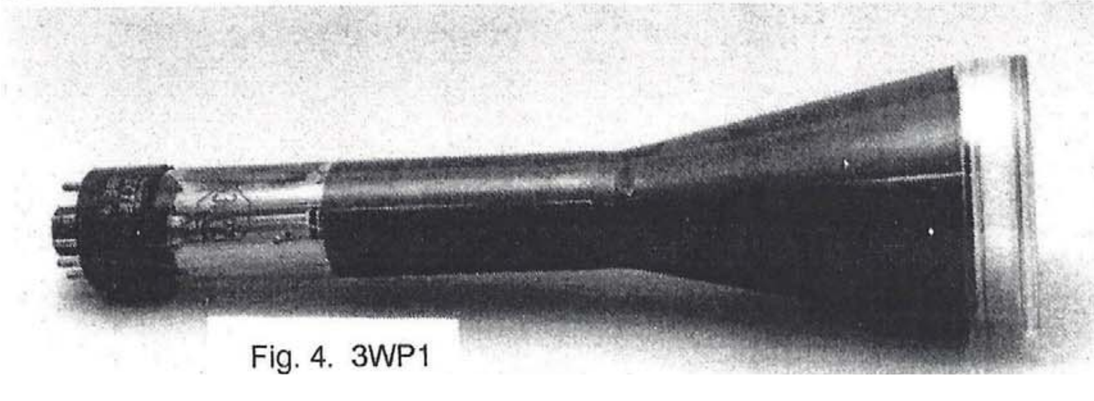


Fig. 4. 3WP1

TUBE	MODEL	INTRO	S/N RANGE	P1	P2	P7	P11
3WP-	310	1955	101-10000	154-058	154-059*	154-060	154-061
"	310A	1959	10001-17372	"	"	"	"
"	315	1953	ALL	"	"	"	"
"	360	1955	101-2576	"	"	"	"
5CP-A	511	1947	ALL	154-062*	N/A	154-063	154-064
"	511A	1948	455-5099	"	"	"	"
"	512	1949	101-2524	154-062	N/A	154-063*	154-064
"	514D	1950	ALL	154-062*	N/A	154-063	"
5XP-	513	1950	101-1887	154-065	154-066*	N/A	154-067
"	517	1950	101-925	"	154-066	"	154-067*
5ABP-	511A	1950	5100-END	154-068*	N/A	154-069	154-070
"	512	1949	2525-END	154-068	N/A	154-069*	"
"	514AD	1953	ALL	154-068*	N/A	154-069	"
"	524D	1954	ALL	"	"	"	"
"	524AD	ca1957	ALL	"	"	"	"

* Denotes phosphor normally supplied

Table 1. Tektronix part numbers for purchased CRTs

sized 310A, now with the Tektronix T310 CRT, remained in the catalog up to 1971 and was very popular. 3WP-s were purchased from RCA, Sylvania, and Du Mont. The 3WP- was registered with RTMA in 1952 by RCA.

TEKTRONIX PART NUMBERS

Many cathode-ray tube type and part numbers have been used since the introduction of the Tektronix 511 oscilloscope in 1947. Because of evolutionary changes in CRT design as well as changes in the Tektronix part numbering systems, several hundred pages of cross-reference lists between instrument type number, CRT type number, and part number exist. Adding to the confusion are the many phosphor and internal graticule variations that were used later. The Tektronix part number during the early years consisted of two groups of three digits separated by a hyphen (example: 154-062). The first three numbers denotes the category of part such as resistor, capacitor, vacuum tubes, etc. CRTs were included in the 154- prefix group for vacuum tubes. Variations observed on the two three-digit groups include omitting the hyphen to make it a single six-digit number (example: 154062) in instruction manuals printed in the late 1950s and the later addition of a letter suffix (example: 154-062A), presumably added to denote production changes or improvements. The latter is found in an internally published p/n cross reference list from 1967 that included early CRTs. The purchased tubes themselves were marked only with the customary RMA type number. Table 1 lists the Tektronix part numbers assigned to purchased CRTs.

COMING NEXT:

The story of Tektronix' shift from a user of off-the-shelf CRTs to a manufacturer of its own precision T51 CRT will be covered in Part 2, "The First Tek CRTs."

REFERENCES:

Keller, Peter A., The Cathode-Ray Tube, Palisades Press, 1991.

Griffiths, Stan, Oscilloscopes, Selecting and Restoring a Classic (, 1992.

Lee, Marshal M., Winning with People: The First 40 Years of Tektronix, Tektronix, 1986.

Tektronix instrument catalogs.

Tektronix internal publications of instrument/CRT/part number cross reference lists, 1962-1989.

TEKTRONIX CRT HISTORY

Part 2. The First Tek CRTs

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Part 1 described the situation leading to the decision in 1951-52 for Tektronix to be-gin design of CRTs for its own use. Another factor of concern in purchasing tubes from a competitor was the inability to request new designs, as it would tip them off as to new product plans. Designing a device as complex as a precision cathode-ray tube involves many technical disciplines. Vacuum technology, glass working, electron-optics, metallurgy, chemistry, materials science, coatings, screening, and electronics are all critical to developing a manufacturable CRT. Many of these apply to convention-al vacuum tubes but the problems in CRT design are multiplied by the high accelerating voltages, volume of the large evacuated bulbs, bulb surface area, life requirements, cost, and the critical alignment required to have a finely focused high-voltage beam of invisible electrons arrive at the center of the screen. A two axis deflection system of prescribed bandwidth, sensitivity and minimum pattern distortion anywhere within the active display area adds to the challenge. All of this was done in the days before the existence of advanced computer programs for electron-optical design. In the early days of Tektronix history, it is especially noteworthy that almost all employees were home-grown. Most of the individuals employed in designing the new CRT were engineers and physicists from Northwest Oregon who had never been involved with CRTs previously. This probably both hindered and helped the task at hand. There was certainly a lot of reinventing of the wheel but conversely, they were not bound by old methods. There was a lot of free-thinking going on and some major improvements to the CRT resulted. When the author joined the CRT Engineering department in 1963 there were still hardly any "outsiders" in the group. At that time Tek had internal cabinet and metal shops that made workbenches, shelves, rolling carts, and even book-ends for company use.

THE T51 AND THE T51

Yes, you read that right. Read on. The Du Mont 5XP- (Figure 1) appears to be the starting point in the design process for the first Tektronix CRT. Figure 2 shows a prototype CRT that must have been about mid-way in the development process. Note that it uses the same bulb as the Du Mont 5XP-, has the Tektronix spiral accelerator, and has an electron gun that looks very much like that of the RCA 5CP-. This would indicate that the coating, sealing, pumping, and finishing processes were fairly well developed at that point but that electron guns were not yet being assembled at Tektronix.

After three years of concentrated effort solving the design and manufacturing problems, production finally began in 1954 of Tektronix's first CRT, the T51P2 (Figure 3). By now the tube design is beginning to look uniquely Tektronix. The T51 was used in the new 10-MHz models 531 and 535 that were a mainstay in the prestigious 530 / 540 oscilloscope series with plug-in vertical amplifiers for which Tektronix became famous. These were the work-horse oscilloscopes found in almost every lab during the late 1950s and the 1960s. Rack-mount versions were available as the RM-31 and RM-35

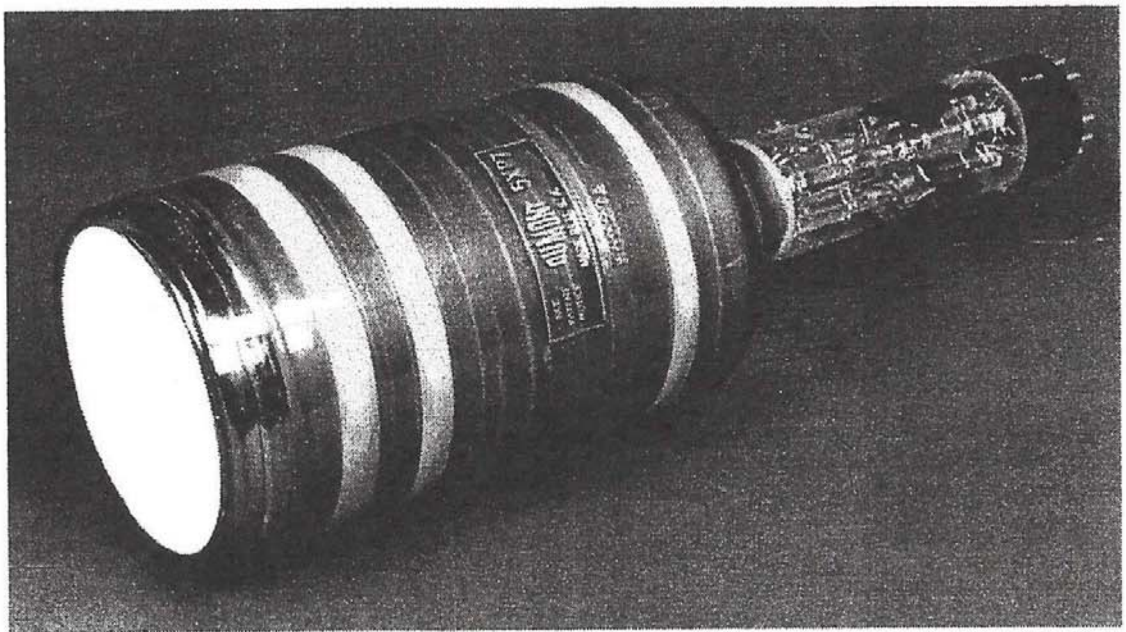

Fig. 1. Du Mont 5XP7

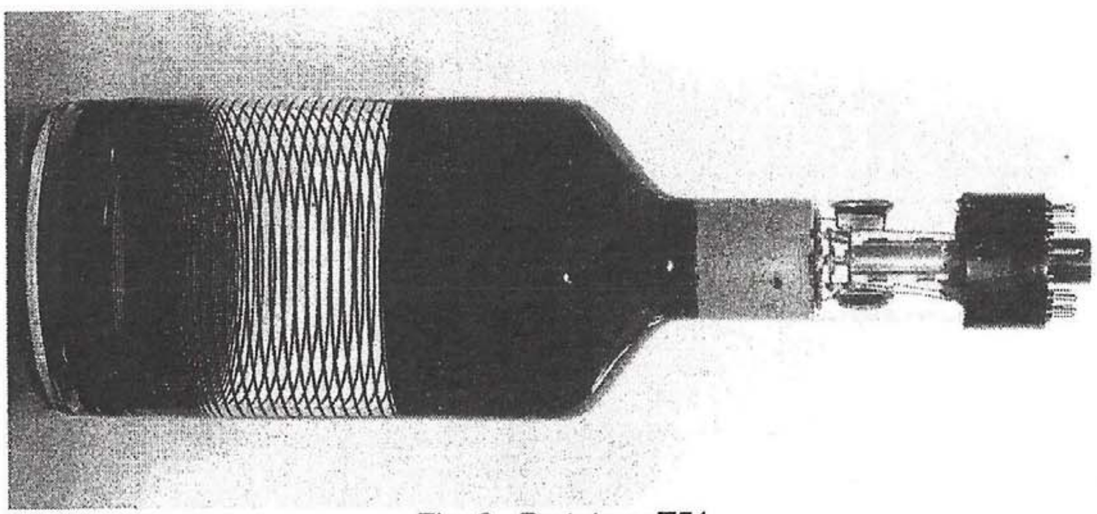

Fig. 2. Prototype T51

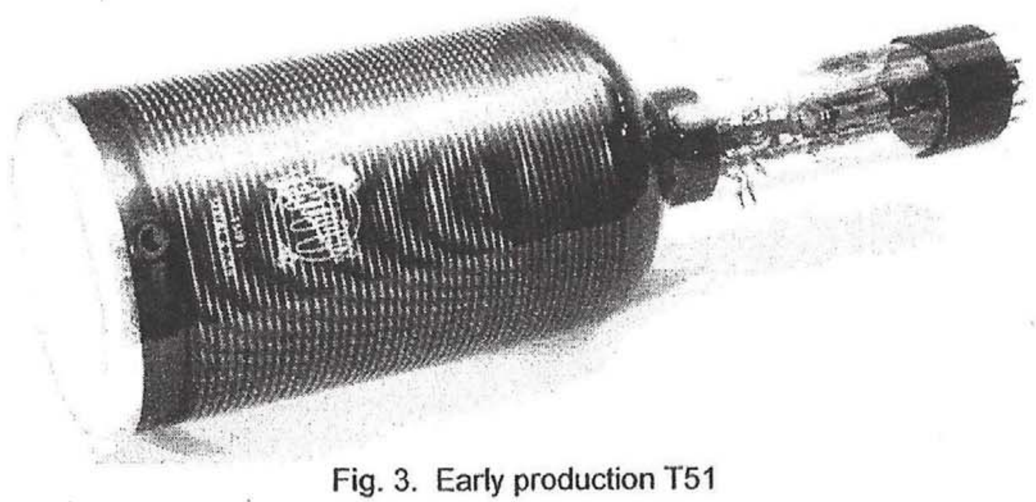

Fig. 3. Early production T51

respectively. The T51 also replaced the 5XP- in the model 513 after serial number 1887.

The early production T51 was another step between the Du Mont 5XP- and the final Tektronix design for the 530 / 540 series instruments. It used the cylindrical flat-face bulb of the 5XP- but instead of the multi-band stepped post-deflection accelerator with its four anode buttons, a single anode button was used near the screen and the Tektronix developed resistive-spiral accelerator provided a gradually increasing acceleration potential along the length of the bulb. This minimized deflection distortion caused by the abrupt changes in the acceleration fields that were present in the Du Mont design. Early 531 and 535 oscilloscopes using this tube are easily identified by the cylindrical mu-metal CRT shield.

Characteristics of the T51 included an acceleration voltage of 10 kV and an aluminized screen for high brightness when viewing and photographing fast single-shot events, 6 x 10 cm scan area, minimal spot and pattern distortion and thin-wire feed-through neck-pin connections to the deflection plates to reduce capacitance loading of the deflection amplifiers for wider bandwidth.

Soon, the bulb of the T51 was changed to the tapered-curve shape (Figure 4) of the common 5ABP-. Of course, painting a uniform resistive spiral accelerator on the tapering curved bulb walls was a problem even more difficult than it had been with the cylindrical bulb. It is estimated that the change of bulb shape occurred in 1955. Instruments with the later production T51 may be identified by a tapered CRT shield. The tube type number and part number remained the same as the early production tubes, hence the title of this section. At about the same time, the bandwidth specification for the model 531 and 535 instruments became 15 MHz.

Several similar CRTs based upon the second T51 design were eventually developed and manufactured for forthcoming 530 / 540 series instruments as well as the 515 oscilloscope, 570 vacuum tube curve tracer and 575 transistor curve tracer. This group of CRTs will be discussed in the next article of this series.

PART NUMBERS AND MARKINGS

Many cathode-ray tube type and part numbers have been used since the introduction of the Tektronix 511 oscilloscope in 1947. Because of evolutionary changes in CRT design as well as changes in part numbering systems, several hundred pages of cross-reference lists between instrument type number, CRT type number, and part number exist. Adding to the confusion are the many phosphor and internal graticule variations that were used.

During the early 1950s, CRT numbering was still simple – a CRT type number used mostly by the engineers who probably couldn't be trusted keep part numbers straight and one part number for the manufacturing, inventory control, accountants and field service folks who wanted a uniform numbering system for all parts. They didn't really care what the part was, just that the numbers on the box matched those on paper and that there were enough of the parts with that number on the shelf. The tube number at least told the engineers something about the tube and its use. In the case of the of the T51P2, T designated that is was a tube (duh!), 5 represented the screen size (5-inch), 1 probably was for the first of the planned series, and P2 denoted a green long-persistence phosphor. The part number, 154-081 for the T51P2, was merely the next available tube number in sequence, in this case. Simple? Yes, so far, but we forgot the customer.

Fig. 4. Later production T51

TYPE-OLD	TYPE-NEW	TYPE-EIA	P/N-OLD	P/N-NEW
T51P1	T0510-1	5BGP1	154-080	154-0080-00
T51P2	T0510-2	5BGP2	154-081	154-0081-00
T51P4	T0510-4	5BGP4		154-0197-00
T51P5	T0510-5	5BGP5		154-0123-00
T51P7	T0510-7	5BGP7	154-082	154-0082-00
T51P11	T0510-11	5BGP11	154-083	154-0083-00
T51P12		5BGP12		154-0101-00
T51P14	T0510-14	5BGP14		154-0117-00
T51P15	T0510-15	5BGP15		154-0096-00
T51P16	T0510-16	5BGP16		154-0092-00
T51P19		5BGP19		154-0121-00
T51P24	T0510-24	5BGP24		154-0124-00
T51P25		5BGP25		154-0150-00
T51P31	T0510-31	5BGP31		154-0342-00
T51P32	T0510-32	5BGP32		154-0379-00

Table 1. T51 Cross-reference list

Fig. 5. Tektronix logo

These were being ordered by engineers who often had special needs, or at least wants, of different phosphor color and persistence. Some of them discovered the JEDEC book of RTMA (formerly RMA) registered phosphors. It contained data on over 20 different phosphors. They began requesting instruments and replacement CRTs with them. The T51 was ultimately available with 15 phosphors, each with its own part number in no particular sequence other than the order that someone asked for that phosphor.

The late 1950s marked the end of simple part numbering at Tektronix. In 1957, the T51 received the EIA (formerly RMA, RTMA, and RETMA) registered type number 5BGP- along with several of the phosphor type numbers appended to the end. The full type number now read T51P2 / 5BGP2 with a part number of 154-081. Tubes have been observed marked T51P2, 5BGP2, and 5BGP2 / T51P2. By 1961 the T51P- was listed as "formerly designated 5BGP-". Problems were being encountered with Electronic Tube Corporation, Sylvania, and others manufacturing and selling inferior tubes under that number to the replacement market, particularly the U.S. government which put out RFQs for open bid. Naturally, they would accept the lowest bid. When the scopes didn't meet their specifications, the customers would complain to Tek. Ending use of the EIA number didn't completely end the problem – companies continued to produce replacement tubes marked with the T-number instead.

In 1963, a couple of "0"s were added to both ends of the two-digit portion of the tube type number and the "P" replaced with a "-," thus making it a T0510-2. To add to the fun, in 1965, the Tektronix part number system was hard pressed to accommodate the many parts required by the company's rapid growth. The first group of three numbers remained the same but the second group of three digits now became four and a two-digit suffix was added to denote changes in the part or variants of it. The part number for the T51P2 became 154-0081-00. This was just the beginning of type- and part-number proliferation. Both of these numbering systems remained in place until 1996 when CRT manufacturing was ended at Tektronix. More insights will be provided in following articles. See Table 1 for the various type and part numbers assigned to the basic T51s with their various phosphors. This was derived from the 1967 cross-reference list. There are a few gaps, possibly a result of the list being compiled a decade later than when the T51 was Tek's most important CRT.

And lastly, while we are on the subject of markings, the fondly remembered "Tek bug" trade mark (Figure 5) was applied in bright yellow paint at the screen end of completed CRTs before shipping up until early 1965. While "busy" by today's streamlined corporate logo standards, the well-respected Tek bug was used for many years and appeared on all products, manuals, catalogs, and even cafeteria chairs, coffee cups and Tektronix-made bookends. Many variations of additional markings may be found on Tektronix CRTs manufactured during the 1954 -64 period. These included:

- Tek-Bug region – The Tek Bug was applied near the screen with it and its associated markings reading correctly with the tube resting on its screen end. The tube type number and phosphor type were usually written just below the Tek Bug. They were marked in the same rich yellow paint. Often the phosphor type was handwritten while the tube type was printed. Early

CRTs also had "Serial XXXX" just below the type number. The serial number has also been observed between the anode button and the screen. Later CRTs had a date code consisting of the week number and the last digit of the year separated by a hyphen or a space and handwritten in yellow paint above the Tek Bug.

- Neck-pin region – Later CRTs had the date code handwritten in yellow paint just above the neck pins so as to be visible through the neck pin cutout in the mu-metal CRT shield. One to three digits of the type number and the serial number separated by a hyphen were handwritten in yellow paint just below the neck pins. An example is "1-31357". In this example, the "1" indicates a T51. As the T52 through T55 were introduced, only a single digit was required to indicate the type.

- Bulb markings – Three digit numbers (no hyphen) stamped in high-temperature metallic ink applied to the bulb in bulb-prep may indicate the processing date. Another 8-digit number is often present but its significance is unknown. It was probably used to identify batches or processing variables. The phosphor type may also be stamped in a similar manner, for instance, "P2" or "P11". These bulb markings are not found on earlier Tek CRTs.

- Focus ring – One to three digits from the CRT type number were usually handwritten in high-temperature black ink on the focus ring. They were not present on early T51 CRTs but became necessary to identify different electron gun types as additional tube types entered production.

- Anode barrel - A serial number, also handwritten in high-temperature black ink, appeared on the first-anode barrel. It was usually the same as the serial number applied to outside of the tube after final test.

- Grid cup - Numbers were usually scratched or penciled on the grid cups. They are suspected to indicate cathode batches or cathode processing dates. Due to the difficulty in reading the markings, no conclusions have been reached as to their significance.

- Crudely handwritten 1- or 2-digit numbers in black paint are sometimes found on the outside of the neck

- Just forward of the base. The purpose of them is unknown but it is hypothesized that they might indicate the test operator or test station in final test.

This is intended only to serve only as a general guide to those CRTs displaying the Tek Bug, since many variations on these markings were employed over the years. It should help identify tubes and manufacturing dates for CRTs with illegible external markings, since the internal numbers may help pin them down. Special thanks to Stan Griffiths for pulling a number of early Tek CRTs from his inventory to allow study of the many different numbering schemes employed.

COMING NEXT

The T51 spawned a whole series of related tubes used in the classic vacuum-tube Tektronix oscilloscopes of the 1950s. These will be covered in Part 3, "The Classic Years."

REFERENCES

See Part 1, TC, June 2006, p. 9.

TEKTRONIX CRT HISTORY
Part 3. The Classics: 1955-59

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Part 1 described the situation leading to the decision in 1951-52 for Tektronix to begin design of cathode-ray tubes for its own use. Part 2 discussed the development of the first Tektronix CRT, the T51, in two different versions. Several similar CRTs with 2-digit type numbers (T52 through T56, and T64-T65) based upon the second T51 design were eventually developed and manufactured for forthcoming 530 / 540 series instruments as well as the 515 oscilloscope, 570 vacuum-tube curve tracer and 575 transistor curve tracer. These tubes differed primarily in deflection sensitivity, bandwidth, scanning area at the screen, acceleration voltages, shields used for geometry and astigmatism mounted in the deflection region, overall length, and naturally lots of different numbers. Most base connections (excluding the dual-beam and dual-gun tubes) are the same except for pins 11 and 12. These were used in some tubes for the geometry and astigmatism control connections. Others had both pins unused. It is sometimes possible to substitute one tube in the series for another, in a pinch, if attention is paid to what is connected to those pins. Sensitivity and bandwidth specifications will not be met in many, if not all, cases. Other early Tektronix CRTs from the classic period included dual-beam*, dual-gun*, monoaccelerator, and even 3-inch tubes. See Table 1 for a listing of type number evolution and important specs for these CRTs. The following describes this series of CRTs in approximately chronological order spanning the years 1955 to 1959.

THE T54

The T54 was the next in the series and was used in the 30 MHz 541 and 545 oscilloscopes introduced in 1955. The 545 and later 545A have always been considered the "most classic of the classics" in the Tektronix scope line. The wider bandwidth vertical

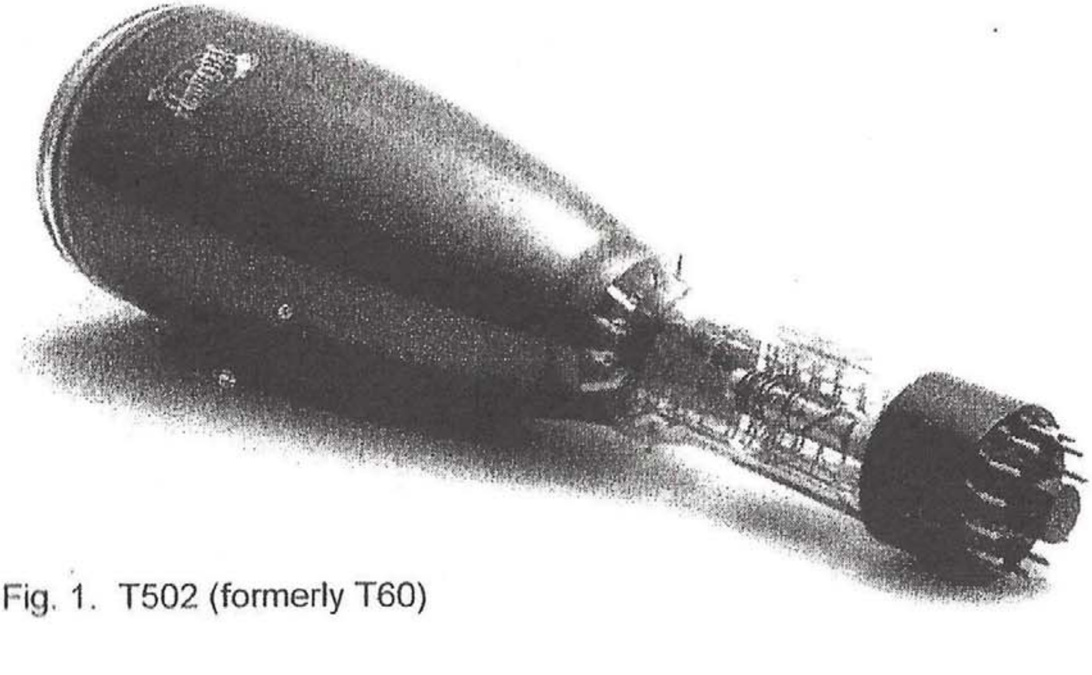

Fig. 1. T502 (formerly T60)

deflection system limited the usable scan area to 4 cm x 10 cm. The meaning of the type number follows that of the T51 except that the 4 likely refers to the 540 series scopes. P2 was the standard phosphor and the T54P2 had the part number 054-098. As with the T51, many phosphors were available, with a corresponding proliferation of part numbers. See Table 2. The T54- was registered as the 5BHP- with RETMA in 1957, about the same time that they became the Electronic Industries Association (EIA). The Tektronix designation became T0540 in 1965 with their revised part-numbering system.

A high-voltage version of the T54 was variously nomenclatured T54PH, T517PH, and T0541. It was employed in the 517A oscilloscope beginning in 1955. An acceleration potential of 24 kV was used for viewing and recording very fast single-shot events.

THE T52

The 570 vacuum-tube curve tracer, announced in late 1955, used the T52P1. In 1957, the 575 curve tracer, also using the T52P1, was introduced to meet the needs of engineers just beginning to explore the use of semiconductors. The T52 was also used in the model 532, a lower-performance version of the 531 as well as the 525 television waveform monitor introduced in 1955. The T52 was an unaluminized CRT operating at 4 kV acceleration potential. See the T55 description below for the rationale behind this. The T52- was registered with EIA as the 5CAP- in 1958. The Tektronix designation became T0520 in 1965 with their revised tube numbering system.

THE T55

In 1956, Tektronix introduced the 515 general-purpose oscilloscope with 15 MHz bandwidth, using the T55P2. The 515 differed from the 530/540 series instruments in that it had a self-contained vertical amplifier instead of a plug-in amplifier. The T55 was of a design similar overall to the T51 with one notable exception. It was designed to operate at only 4 kV and therefore was unaluminized. At only 4 kV, beam penetration of an aluminum layer is poor unless the layer is quite thin. The result is little, if any, gain in brightness and poor brightness uniformity due to slight variations in aluminum thickness across the screen. The 516, a dual-trace* version of the 515, was introduced in 1960. It used the same T55P2 CRT. The T55- was registered with EIA as the 5CBP- in 1958. The Tektronix designation became T0550 in 1965 with the revised part numbering system.

THE T31

In 1957, a 3-inch portable oscilloscope, the type 316, was introduced. The 316 had many of the features of its larger Tektronix counterparts. The 10 MHz bandwidth specification necessitated a CRT with lower deflection-plate capacitance than that provided by the purchased 3WP- CRTs used in the earlier 310 and 315 models. The solution was a tube similar to the 3WP- but having the deflection plate connections brought out directly through neck pins instead of the base. P2 was the standard phosphor. For reasons unknown, the T31 was replaced by the T32 about 1959.

THE T56

Another 1957 introduction was the 536 X-Y oscilloscope using the T56P2 CRT. The 536 was unusual in its use of the 530/540 series plug-in amplifiers for both vertical and horizontal deflection. Deflection sensitivity specifications of the vertical and horizontal CRT deflection plates are identical. The T56 also operated at 4 kV and was unaluminized. The T56 was not regis-

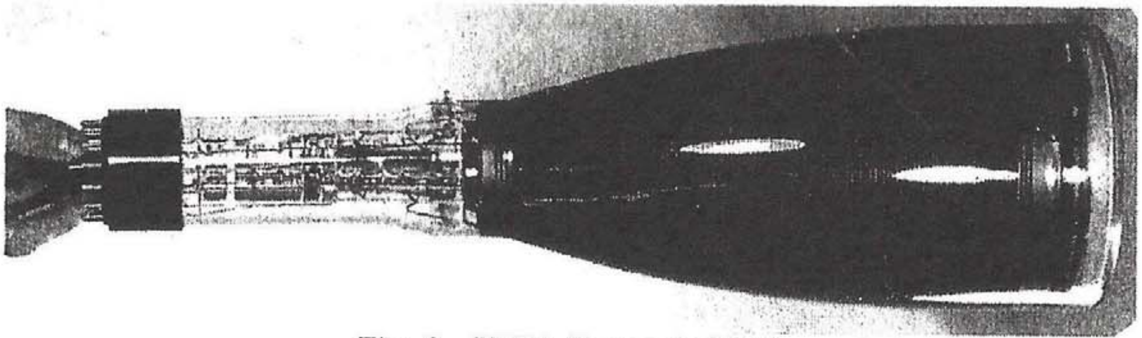

Fig. 2. T551 (formerly T57)

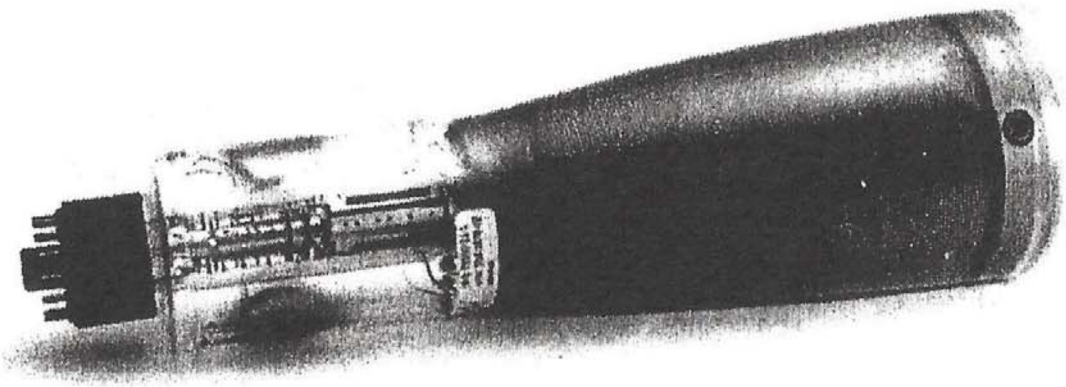

Fig. 3. T5550 (formerly T59, T555)

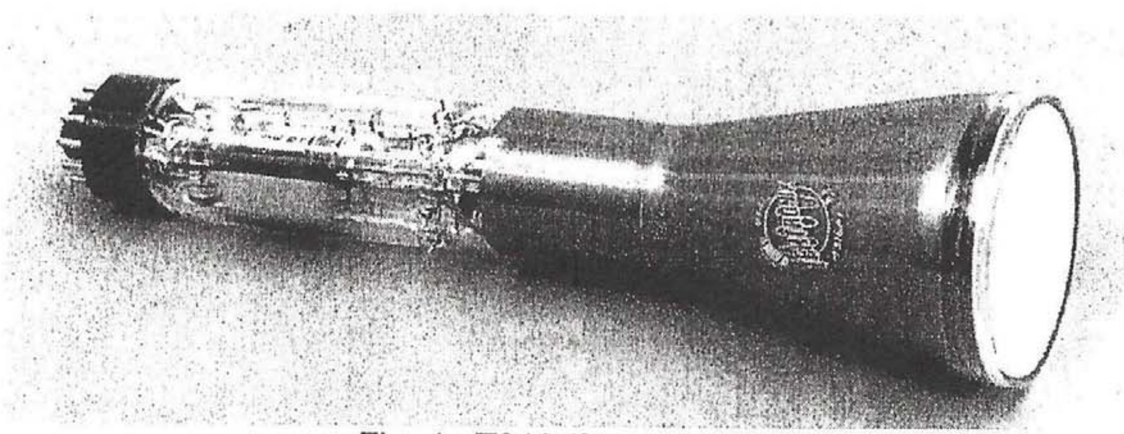

Fig. 4. T316 (formerly T32)

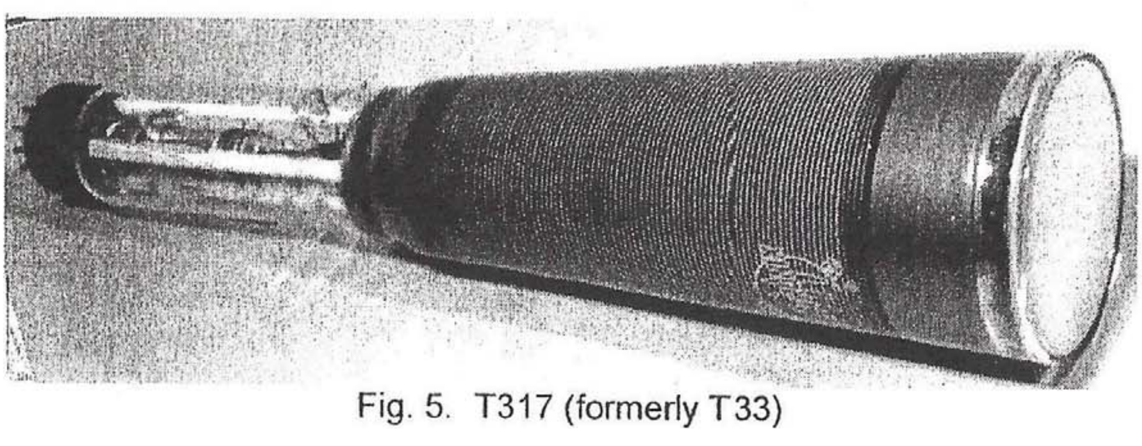

Fig. 5. T317 (formerly T33)

tered with EIA. The Tektronix designation first became T536 in 1959, and later, T5360 in 1965 with the revised part-numbering system.

THE T65

The T65 designation was used for only about one year. In 1958, the 543 oscilloscope was introduced, with a slightly modified version of the T54P2 which was the T65P2. The 543 was similar to the 541 except for having high horizontal scan magnification and improvements in the horizontal-sweep configuration that were to become a part of all improved 540-series scopes. The T65 became the T543 in 1959 and the T5430 in 1965. It was also registered with EIA in 1964 as the 5ELP-.

THE T60

One of two Tektronix dual-beam* oscilloscopes, the 502, was announced in 1958. It was a rather specialized instrument having an extremely high vertical sensitivity of 200 microvolts/centimeter with only 100 kHz bandwidth, increasing to 1 MHz at 0.2 V/cm. The T60P2 (Figure 1) had two electron guns with a common pair of horizontal deflection plates. This allowed two time-related signals to be displayed simultaneously. The T60 was a monoaccelerator CRT operating at only 3 kV. It became the T502 in the 1959 renumbering and T5020 in 1965. 502 scopes above serial number 1720 and 502-A's used a slightly modified T5020 designated the T5021. It differed in the base pin connections which provided additional connections and a raster-alignment electrode in the anode system to permit registration adjustment of the two beams. An external shorting strap between pins 3, 6, and 8 allowed the T5021 to be used in older 502s.

THE T57

Also in 1958, another Tektronix dual-beam* CRT was employed in the 551 oscilloscope. Bandwidth was intermediate between that of the 530 and 540 series instruments. The T57P2 CRT (Figure 2) operated at a full 10 kV and was constructed similarly to the other 530/540 series scopes except for a bulge in the neck diameter to accommodate two electron guns. The T57 soon became the T551 in 1959 and the T5511 in about 1965. The later change must have coincided with some slight and unknown design change since the type number would have logically been expected to become T5510.

THE T64

The 1959 introduction of the T64 for the 530-series instruments paralleled that of the T65 for the 540-series. It was merely an improved version of the original T51 and was initially employed in the new 533 oscilloscope and the subsequent 531A and 535A. The standard phosphor was P2. It quickly became the T533 and in 1965, the T5330. For some reason, no EIA registration was ever applied for despite its wide spread usage and being from the same time period as the T65.

THE T59

The first true dual-gun* CRT, the T59P2 (Figure 3), was used in the 555 oscilloscope introduced in 1959. It was essentially two complete T54 electron guns in a single bulb. By not sharing a common set of horizontal deflection plates as in the T57 and T60, two completely unrelated signals could be viewed together. The T59 immediately became the T555 and eventually the T5550 in 1965.

THE T32

The T32 (Figure 4) replaced the earlier T31 in thee type 316 portable oscilloscope at about the time of the 1959 changes to three-digit type numbers.

TYPE	YEAR	USED IN	EIA	1959	1965	A2	SCAN	LENGTH	NOTES
T31	1957	316	---	---	---	1.85 kV	8x10 div	11-1/2"?	Replaced by T32
T32	1958	316	---	T316	T3160	1.85 kV	8x10 div	11-1/2"	Monoaccelerator
T33	1959	317	---	T317	T3170	9 kV	8x10 div	13-5/8"	
T51	1954	531, 535	5BCP-	---	T0510	10 kV	6x10 cm	17-1/2"	
T52	1955	525, 532, 570, 575	5CAP-	---	T0520	4 kV	8x10 cm	17-1/2"	
T53	1959	507	---	T507	T5070	24 kV	6x10 cm	17-1/2"	
T54	1955	541, 545	5BHP-	---	T0540	10 kV	4x10 cm	18-1/8"	
T55	1956	515, 516	5CBP-	---	T0550	4 kV	6x10 cm	18-1/4"	
T56	1957	536	---	T536	T5360	4 kV	8x8 cm	17-1/8"	Identical V and H sens.
T57	1958	551	---	T551	T5511	10 kV	4x10 cm*	18-1/2"	Dual-beam
T59	1959	555	---	T555	T5550	10 kV	4x10 cm*	18-3/4"	Dual-gun
T60	1958	502	---	T502	T5020	3 kV	8x10 cm	18-3/16"	Monoaccel., dual beam
T64	1959	531A, 533, 535A	---	T533	T5330	10 kV	6x10 cm	17-1/2"	
T65	1958	541A, 543, 545A	5ELP-	T543	T5430	10 kV	4x10 cm	18-1/8"	
T66	1959	526	---	T526	T5260	4 kV	Full	16-15/16"	Monoaccelerator

* Each beam has 2 cm overlap for 6x10 cm total active screen area

Table 1. Classic Tektronix CRTs

The 1959 instrument catalog states that the "(T316) T32 . . ..replaces the T31 with minor circuit changes." .In 1965, it became the T3160. P2 was the standard phosphor for the 316.

THE T33

The T33 (Figure 5) was an especially interesting tube that was also announced in 1959. It was a 3-inch diameter CRT with the now-familiar spiral accelerator, operating at 9 kV for a very bright trace. It was also about 2-inches longer than other 3-inch CRTs, which aided deflection sensitivity. The T33P2 was used in the model 317 portable oscilloscope having 10 MHz bandwidth. The T33 designation immediately became the T317, and in 1965, the T3170.

THE T53

The T53P11 was used in 1959 in the 507 oscilloscope for high-voltage surge testing. The T53 designation was very brief and is listed as a T507P11 in the 1959 catalog. The T53 number may have lasted only through the engineering phases. It became the T5070P11 in the 1965 renumbering scheme. The acceleration voltage was 24 kV and the scan area 4x8 cm.

OPTIONS AND PART NUMBERS

As with the T51, many phosphor options were available, each with an individual Tektronix part number. These are listed in Table 2. Standard JEDEC phosphors available for most Tektronix oscilloscopes were P1, P2, P7, P11, and later, P31. For detailed information on the differences between the phosphor type numbers refer to JEDEC Publication 16 listed in the Reference section at the end of this article. As you can see, the number of CRT part numbers was beginning to get out of hand. Note that all tube and part numbers changed in the 1965 renumbering of tube types and part numbers. The part numbers were expanded from the 3x3 format to a 3x4x2 format. For example, the 154-216 became the 154-0216-00. Also, evolutionary changes were made to the CRTs which resulted in totally different part numbers being set up for later versions of the tubes. A prime example was the change to internal graticules in the mid-1960s. It is beyond the scope of these articles (and the author's tolerance to mental fatigue!) to include them.

*Important distinctions:

Dual-trace - Two different waveforms with a common time-relationship may be displayed simultaneously on a single gun CRT by either displaying them on alternate sweeps or by rapid electronic switching (chopping) between the two signals.

Dual-beam - Two electron guns within a single CRT envelope but sharing a common pair of horizontal deflection plates, time-base, and amplifier. As with a dual-trace scope, the two vertical signals applied to the CRT must be time-related.

Dual-gun – Two completely independent electron guns within a common CRT envelope. Since two sets of horizontal deflection plates are used, two signals differing in both timing and amplitude may be viewed simultaneously.

COMING NEXT

The CRTs discussed in this article were based almost entirely on innovations developed for the original T51 and existing monoaccelerator CRT technology. The next article in this series will discuss the CRTs with the additional power, deflection sensitivity, and beam-expansion innovations required for the first Tektronix transistorized and hybrid oscilloscopes beginning in 1960. Also to be discussed will be other CRTs used to round out

Corrected Table 2 for Peter Keller's "Tektronix CRT History, Part 3. The Classics: 1955-59"

Table 2. Tektronix Part Numbers

TYPE	P1	P2	P4	P5	P7	P11	P12	P13	P14
T31	154-138	154-131			154-142	154-148			
T32/T316	154-154	154-155			154-156	154-157	154-201		
T33/T317	154-216	154-196		154-412	154-217	154-218			
T51/5BGP	154-080	154-081	154-197	154-123	154-082	154-083			154-117
T52/5CAP	154-093	154-097		154-129	154-102	154-103			
T53/T507	154-331				154-239	154-137			
T54/5BHP	154-106	154-098	154-198	154-111	154-104	154-099	154-141	154-166	154-110
T55/5CBP	154-125	154-120		154-369	154-126	154-127	154-192		
T56/T536	154-140	154-133	154-214	154-242	154-135	154-136	154-193		
T57/T551	154-186	154-160		154-210	154-189	154-143			
T59/T555	154-219	154-199		154-328	154-220	154-211			
T60/T502	154-172	154-144		154-236	154-170	154-173	154-211		
T64/T533	154-178	154-165	154-238	154-241	154-179	154-180			
T65/T543/5ELP	154-181	154-175	154-312	154-262	154-182	154-183			154-334
T66/T526	154-231	154-225							

TYPE	P15	P16	P19	P20	P24	P25	P27	P31	P32
T31					154-145				
T32/T316		154-158			154-159			154-345	154-383
T33/T317	154-329	154-325						154-346	154-384
T51/5BGP	154-096	154-092	154-121	154-203	154-124	154-150		154-342	154-379
T52/5CAP	154-330	154-162	154-176					154-343	154-380
T53/T507								154-415	
T54/5BHP	154-122	154-118	154-153		154-152	154-164		154-409	
T55/5CBP	154-151	154-161	154-139		154-177			154-344	154-381
T56/T536	154-184	154-169	154-190					154-351	154-391
T57/T551					154-237				
T59/T555			154-333					154-353	154-394
T60/T502		154-256					154-213		
T64/T533	154-235	154-194	154-222					154-350	154-390
T65/T543/5ELP	154-243	154-227	154-234		154-263			154-339	154-392
T66/T526									

the product line to cover diverse customer requirements.

REFERENCES:

Keller, Peter A., The Cathode-Ray Tube, Palisades Press, 1991.

Griffiths, Stan, Oscilloscopes, Selecting and Restoring a Classic, 1992.

Lee, Marshal M., Winning with People: The First 40 Years of Tektronix, Tektronix, 1986.

Tektronix instrument catalogs.

Tektronix internal publications of instrument/CRT/part number cross reference lists, 1962-1989.

Electronic Industries Association, "Optical Characteristics of Cathode Ray Tube Screens," JEDEC Publication 16, June 1960.

ADDENDUM TO PART 1

In further researching part numbers for this article, a Tektronix part number was found to have been assigned to the 3KP1 early in the part numbering system. Vacuum-tube part numbers from 154-001 to 154-056 were all receiving and special purpose tubes, in order of tube registration number, starting at 0A2 and continuing to type 6080. The first CRT (154-057) listed is the 3KP1, although no known Tektronix instrument employed it. Other purchased CRTs follow it, again in order by type and phosphor, ending at 154-074 (5ADP11). Apparently, all of these part numbers were assigned as a group around the time that the T51P2 (154-076) was introduced. At part number 154-075, the listings changed to chronological order. It is conceivable that the curved-face 3KP1 was initially used in the engineering phase of the 315 oscilloscope and was assigned a part number in anticipation of using production quantities. As far as existing records show, the 315 was manufactured only with the flat-face 3WP- type. It is hard to envision any other explanation unless it was intended for another early instrument that never made it into production.

The 5ADP- type, also found in the same part-number list, may be easier to explain. The Du Mont 5ADP- series was essentially the same as the RCA 5ABP- series CRT used in several early Tektronix oscilloscopes. It may have been simply a case of second-sourcing. It must not have been used often since it is rarely, if ever, found in Tektronix instruments. The logical explanation for that may be that it likely was higher priced than the RCA 5ABP- series, as was often the case with Du Mont CRTs, and the fact that Du Mont was the principal competitor of Tektronix. Part numbers for the 5ADP- series included 154-071 for the 5ADP1, 154-072 for the 5ADP2, 154-073 for the 5ADP7, and previously mentioned 154-074 for the 5ADP11.

RCA's "meatball" logo, Arabic version

TEKTRONIX CRT HISTORY
Part 4. Innovations: 1959-1961

Peter A. Keller
Aloha, Oregon

Part 1 described the situation leading to the decision in 1951-52 for Tektronix to begin design of cathode-ray tubes for its own use. Part 2 discussed the development of the first Tektronix CRT, the T51, in two different versions. Part 3 covered the classic Tektronix vacuum tube oscilloscope CRTs during the period of about 1955 to 1959. It was originally intended that Part 4 would cover the period from 1960 to 1965. It was soon found that the sheer number of innovations during that period would mean leaving out too much interesting information in order to keep it to a manageable length. This installment now covers the CRTs for the first transistorized oscilloscope and some of the more specialized instruments of the late vacuum tube era.

The following describes these tubes in approximate chronological order spanning the years of 1959 to 1961. Bear in mind that introduction dates may vary by a year so depending on information source. Sometimes instruments might be announced prematurely to meet a trade show deadline or unforeseen bugs would appear when an instrument or CRT was introduced into manufacturing. Also, product development times could differ greatly dependent on design complexity. Two products with the same introduction date might have begun design engineering a year or two apart. This might be especially true if one used an existing CRT and the other needed one having untried innovations. This applied as well to how much existing circuit design could be reused in a new instrument.

One thing is apparent from some of the descriptions below; the CRT had stringent requirements placed on it and it was often the limiting factor for the final instrument performance specifications. There were many trade-offs possible in CRT design. These necessitated close working relationships and performance compromises between the CRT design engineers and the circuit design engineers. Examples include deflection sensitivity, deflection plate capacitance (limits bandwidth), brightness, writing rate, spot size, pattern distortion, power requirements, tube length, and cost. Another problem is that if you build a new circuit and it doesn't function properly, you make component value and connection changes until you obtain the desired performance. Corrections could often be made in minutes. With a new CRT, if it didn't work properly, you threw it away and started building another, a process measured in days and dollars. This was particularly true for the T519 described in this article and even more so for the T564 storage tube to be covered in a forthcoming article in this series. And there were often hidden defects such as shorts, opens, misalignment, contamination, foreign particles, or gas, most of which weren't obvious until you tried to operate the tube. I have even seen an unlucky housefly that was inadvertently sealed in a CRT.

T581

The T581 of 1959 probably fits better in Part 3 but didn't fit the two-digit

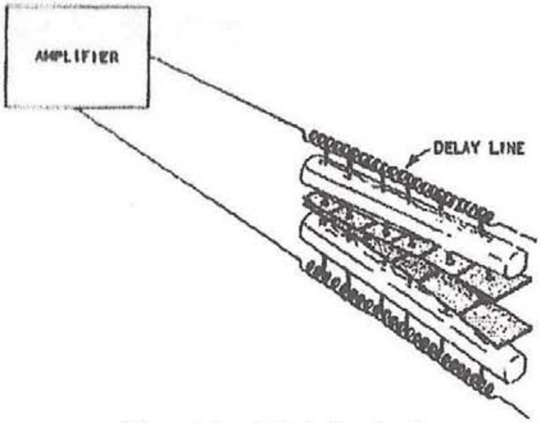

Fig. 1A Distributed deflection system

tube type numbers that article was limited to. The T581 was used exclusively in the Model 581 and 585 oscilloscopes which had a 100 MHz bandwidth (specification reduced to 95 MHz in 1962), and their replacements, the 85 MHz Model 581A and 585A of 1963 (reduced to 85 MHz in 1964). All four were fundamentally similar to the 30 MHz Models 541 and 545.

The T581 was another outgrowth of the original T51 with a couple notable exceptions, both of which were necessary to meet the wide bandwidth specification. The most notable innovation was the distributed vertical deflection system (Figure 1A). This consisted of a series of deflection plates connected sequentially with coils. The capacitance of the deflection plate pairs combined with the inductance of the coils to form a delay line terminated at the screen end (Figure 1B). The velocity of the electron beam matched that of the signal traveling down the delay line, thus reinforcing the deflection over the entire length. The deflection plates were effectively lengthened for more deflection sensitivity. If the plates had merely been combined to make longer ones of equivalent physical length the capacitance would have been prohibitively high and bandwidth severely limited. The T581 was also approximately 2-1/2 inches longer than the T54 CRT to obtain a greater "throw" distance and also allow for the longer vertical deflection system. This further allowed the deflection at the screen to be greater. Even with all that, useful scan area was limited to 4 x 10 cm, equivalent to that of the T54.

Several thousand 581s and 585s were manufactured but they never gained the wide appeal of the classic 530 and 545 series instruments. This probably is due to the fact that while the 80-series plug-in vertical amplifiers were physically the same size as the letter-series plug-ins, a Type 81 plug-in adaptor was necessary to use the widely available letter-series plug-ins of the 530 and 540 series instruments. The adaptor extended the plug-ins out about two inches from the front panel and always looked like an afterthought. Despite that, all letter-series met their full specs in the 580-series instruments.

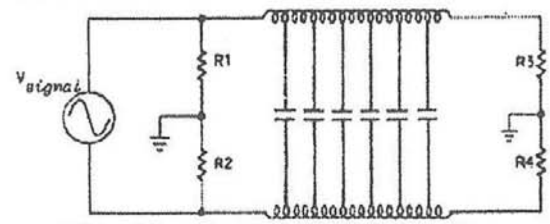

Fig. 1B. Deflection delay line

The T581 became the T5810 with the 1963 tube type number changes. P2 phosphor was originally the standard phosphor supplied, with P31 replacing it in 1962 because of its higher brightness and writing rate. P1, P7, P11, P16, P20, and P32 were also available for the T581 (see Table 1).

T321

The first all-transistor Tektronix oscilloscope was the battery-operated portable Model 321 in 1960. I can well remember the Albuquerque Field Engineer, Dean Butts, walking into my lab in Alamogordo carrying an operating 321 scope shortly after they were publicly announced. It was a real eye-opener in those days when many oscilloscopes would briefly dim the lights at turn-on. Ten D-cell flashlight or rechargeable batteries powered the 321. Alternatively, AC power or external DC power could be used where appropriate.

The CRT used in the 321 was the T321P2 that physically closely resembled the T317 CRT used in the Model 317. A low-power heater drawing only 2 watts, compared to the usual 4 watts of almost all other CRTs of that time period, was used to reduce power requirements. The heater voltage was the customary 6.3 volts. A 4-kV overall acceleration potential gave a fairly bright trace even in outdoor field applications. The principal design problems to be overcome were to keep voltage swings to a minimum for deflection amplifiers and retrace blanking. The early transistors used had low collector breakdown voltage ratings, and of course, Tektronix was usually very conservative with their designs. The 321 operating temperature range was specified as 30 to 120 deg F and altitude to 20,000 feet. Another factor was cost, as higher-breakdown-voltage transistors were markedly more expensive in 1960.

To minimize the deflection amplifier output voltage required, several means were used. First, the acceleration voltage through the deflection region of the CRT was about half of that of the T317. This automatically doubled the deflection sensitivity. A spiral post-deflection accelerator provided the final 4 kV acceleration for a brighter trace while maintaining good deflection sensitivity. Second, the deflection plates were made as long as possible consistent with low capacitance to meet the 5 MHz bandwidth specification. Lastly, the deflection plates were spaced together as closely as possible for maximum sensitivity at the sacrifice of some scan area due to beam intercept by the plates. The specification for scan area was 6 x 10 divisions, each division being ¼". The viewable screen area was masked to that size by the instrument bezel.

Retrace blanking is used in all but the simplest of oscilloscopes to eliminate visibility of the beam as it returns to the left side of the screen prior to its next scan. If the beam is not blanked during that time, a spurious trace will be displayed on the screen. Normally, a pulse of up to -100 volts is applied to the control grid or +100 volts applied to the cathode for cutoff of the beam during retrace. The T321 employed a novel approach to the problem. The first anode region is split and two pairs of cross-connected blanking plates are inserted between anode apertures (Figure 2). The beam passes be-

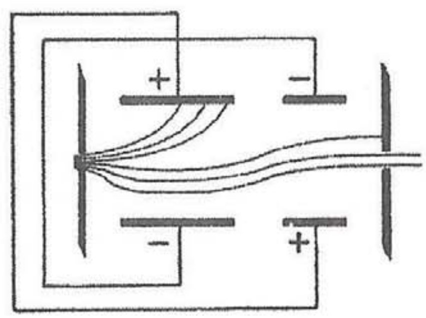

Fig. 2. Blanking plates

tween the plates much the same as it does the deflection plates. If the plates are at the same voltage as the anode apertures, the beam will pass unimpeded to the screen. Applying a differential voltage to the plates will deflect the beam off-axis and it will be intercepted by the second aperture thus preventing it from reaching the screen. It would appear at first glance that a single pair of blanking plates would be adequate but some electrons in the first anode region are divergent and will result in a spot shift at the screen during the blanking transition

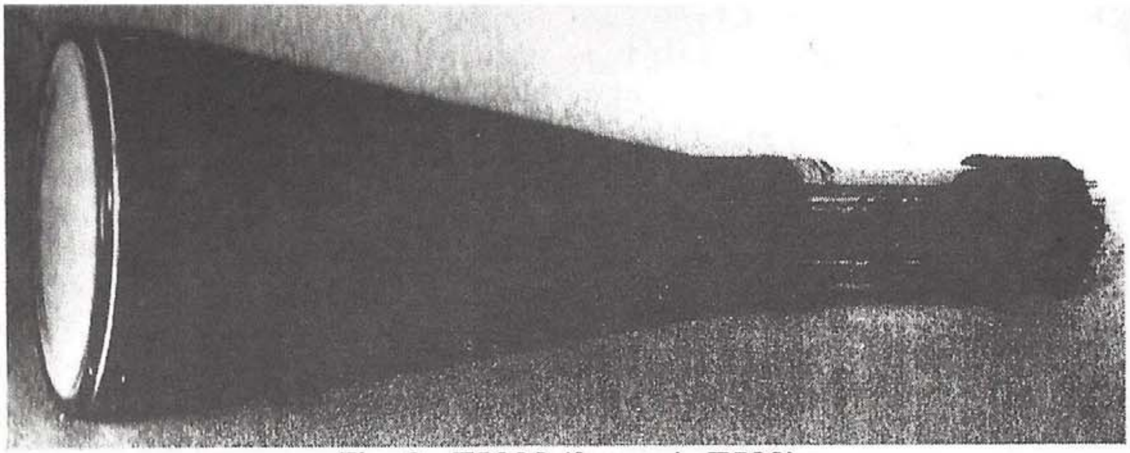

Fig. 3. T5030 (formerly T503)

times. The second pair of plates and cross-connection eliminates the problem. Only about 25 volts, well within the capability of the 1960-era transistors, was required for full blanking.

P1, P7, and P11 phosphors were also available in the T321. The standard phosphor was changed to P31 in 1962 for higher brightness. The T321 became a T3210 in the 1963 type renumbering and evolved into the T3211 used in the Model 321A oscilloscope. The T3211 was a direct retrofit replacement for the T321 and T3210. The reverse is not true since at some point between the original T321 and the T3211 a deflection-plate shield connected to pin 9 was eliminated. It is not clear exactly when but it appears to have been at 321 s/n 4720, coincident with the T3211 introduction.

T503

A pair of low-cost oscilloscopes was introduced in 1960. These, the Model 503 and 504, were basic instruments intended for the education market where Du Mont and other lower cost oscilloscopes were entrenched. The 503 and 504 retained the "Tek look and feel" but had a bandwidth of only DC to 450 kHz.

The 503 and 504 both used the T503 (Figure 3) which physically had a strong resemblance to the Du Mont 5AMP- except for being a little shorter and having Tektronix-style neck pins instead of the Du Mont small ball caps. Normally, neck deflection lead connections are not necessary for the 450-kHz bandwidth of these instruments but the tube was also to be used the following year in the Model 560 and 561 moderate-cost plug-in oscilloscopes that had wider bandwidth. The T503 was an unaluminized mono-accelerator CRT operated at 3 kV in the 503 and 504 and 3.5 kV in the 560 and 561. The tube was not particularly noteworthy except that it used blanking plates like the T321.

Both instruments were normally supplied with P2 phosphor manufactured by General Electric. This particular P2 had much better brightness and a very pleasing bluish-green color. It was a marked improvement over previous P2s. Because of its excellent long decay properties and the low frequency applications emphasis of the 503 and 504, it remained the standard phosphor long after most other instruments changed to P31 phosphor. P1, P7, and P11 were catalogued as optionally available. CRTs with P16, P19, P31, and P32 (see Table 1) were eventually part numbered and available through Customer Service on special order. The T503 became the T5030 and was later produced in rectangular versions as the T5031, T5032, and T5033.

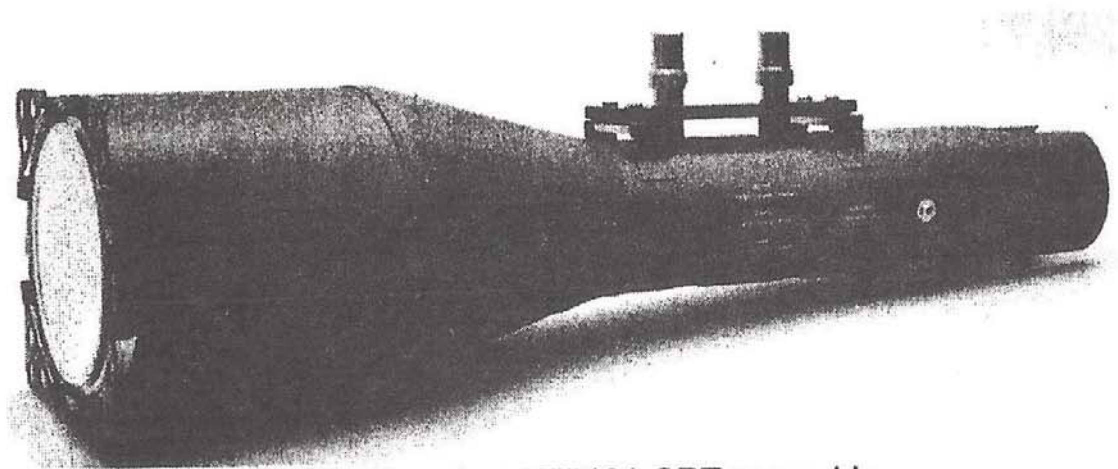

Fig. 4. Completed T5191 CRT assembly

T519

In 1961, the 519 oscilloscope was introduced. With a bandwidth of DC to 1 GHz and a risetime spec of less than 0.35 ns, it was state-of-the-art for viewing and photographing high-speed events. Extensive nuclear testing during the 1960s provided a high-end niche market for the 519 to record sub-nanosecond pulses from nuclear events. Legends abound of trailers containing rows of 519s with C19 cameras affixed to record just a single pulse from each of various aspects of the nuclear explosions. It was rumored that they often became contaminated and bulldozed into the ground, thus ensuring a great replacement market at about $3800 a pop (or should I say boom?). The 519 was produced until about 1973.

The 519 used the T519 CRT that was a major departure from other Tektronix CRTs. Many unique features were incorporated in this CRT. It resembles previous Tektronix CRTs only in its use of a spiral accelerator.

Mechanically, the T519 used a bulb and spiral accelerator similar to the other five-inch tubes except for having another small-cavity anode button to connect to the low-voltage end of the helix. Also, larger diameter neck tubing was used to provide adequate space for the complex deflection system. The base was the first "hard-pin" type used on Tektronix CRTs. Instead of the usual Bakelite base cemented to the tube with the wire leads from the header soldered to the base pins, heavier leads used as feed-throughs became the actual pins. A plastic guide / protector slipped over the pins and was secured with RTV silicone rubber. It is possible that the hard-pin stem was used to reduce capacitance for the fast blanking pulses required. The entire tube was permanently mounted in a blue mu-metal magnetic shield (Figure 4).

The greatest difference, though, was in the 1 GHz vertical deflection system. This was constructed as a box-like assembly (Figure 5) with tuning adjustments that were aligned electrically before sealing in the tube. A strip-line deflection plate created a coaxial delay line as in the T581, only for a much higher frequency. The impedance of the line was 125 ohms and General Radio GR-874 coaxial connectors were used for both the input and termination connections. The stripline formed one deflection plate with the velocity of signal propagation through the stripline matching that of the electron beam through the deflection system. The anode voltage could be adjusted to match the transit time of the beam through the deflection system to that of the electrical signal through the stripline deflector for opti-

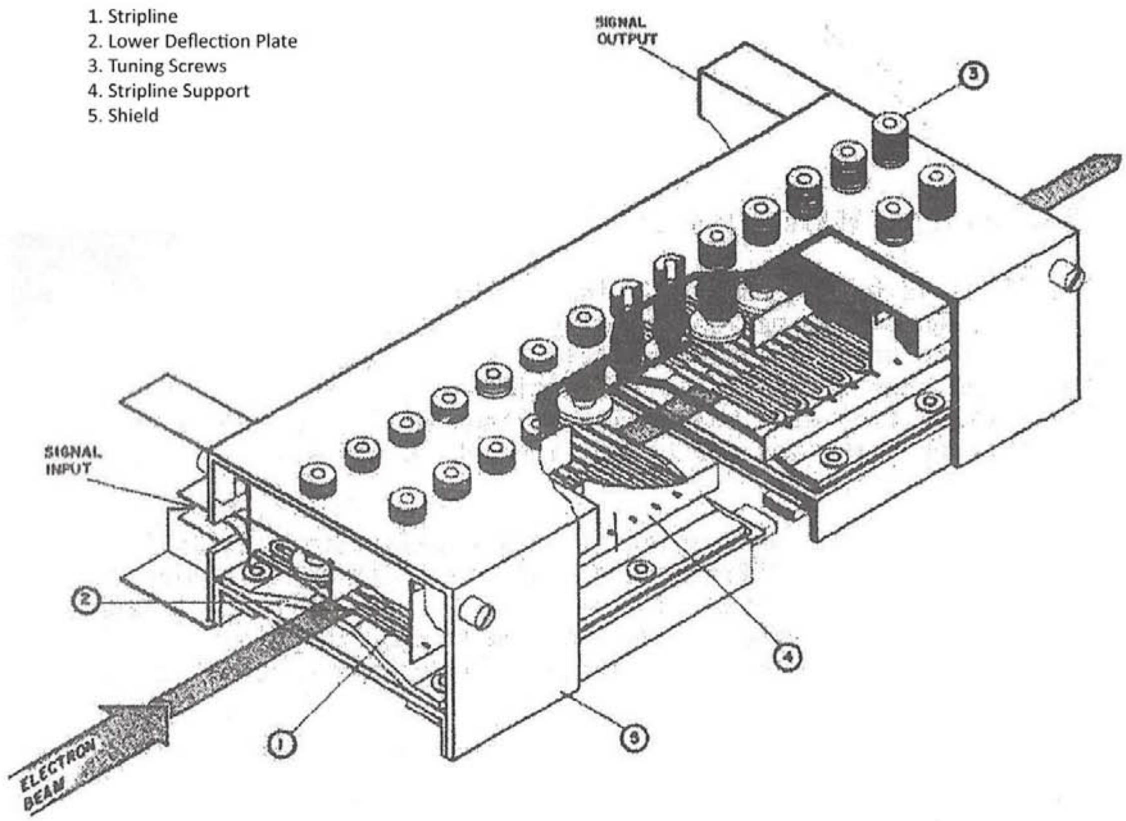

Fig. 5. T5191 stripline vertical deflection assembly

mum transient response. Since the T519 operated with coaxially-fed signals, the deflection was not push-pull and a solid plane formed the opposing deflection plate. No deflection amplifier was possible for the 1 GHz limit so signals were applied to the deflection system directly through coaxial cable. The vertical-sensitivity spec was 8 to 10 volts / cm. Horizontal deflection was more traditional, with the exception of use of a forced-air cooled Eimac 4CX250F as a sweep generator to obtain fast sweeps up to 2 ns / cm.

The overall acceleration voltage was 24 kV. Usable scan area at the screen was 2 x 6 cm and the actual calibration of the deflection sensitivity and risetime of the individual CRT was written on the bezel. Since bezels are often removed and can be lost or mixed up, later T519s had the sensitivity and risetime printed on a label attached to its shield. A very small spot size of 0.004" was obtained in the T519 through electron gun design to aid resolving pulse detail in the limited scan area. Conventional Tektronix CRTs had spot-sizes of 0.010" to 0.015" or so.

The standard phosphor for the T519 was P11 for photo-recording. No other phosphor was available. The T519 soon was renumbered T5190. At instrument s / n 244 it became the T5191, which was the same tube with a slightly degraded vertical sensitivity specification, presumably to improve production yields.

T519C

An interesting variation of the T519 was the T519C that was renumbered as the T5192 (Figure 6). It was used in a special-order version of the 519 oscilloscope designated 519 Mod 795. It is believed to have been developed for Lawrence Livermore Laboratory, a major 519 user. The T519 was built in the Tektronix Engineering Tube

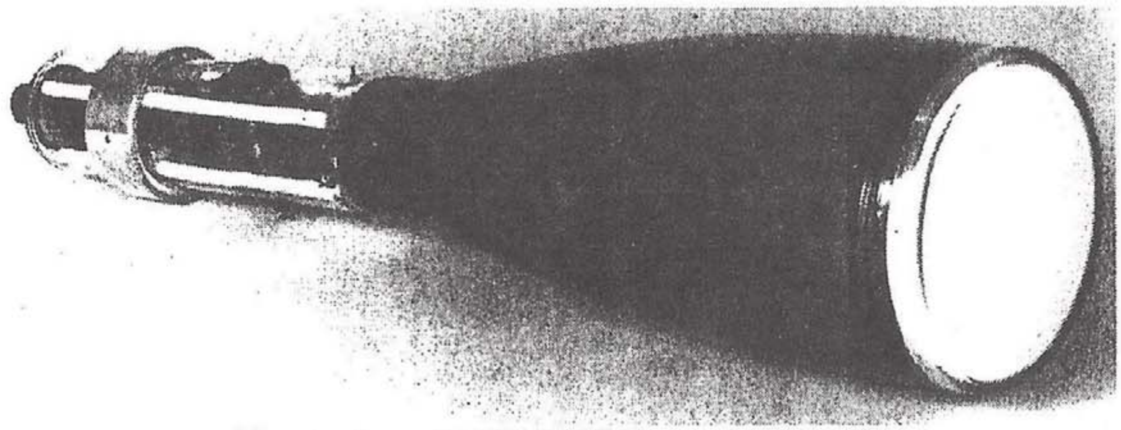

Fig. 6. Raw T5192 CRT (formerly T519C)

Lab. As with the T519, the only phosphor supplied was P11 for photo-recording.

A coaxial vertical deflection system replaced the stripline of the T519 for a risetime spec of 0.13 ns and about 2.7 GHz bandwidth. The increased bandwidth came at the expense of deflection sensitivity. The sensitivity specification was 180 to 240 volts/cm, about 25 times that of the T519. Useable scan area was also decreased to 2 x 4 cm. Most of the P11 phosphor on the five-inch diameter screen never saw an electron. The deflection system consisted of a coaxial transmission line entering the right side of the CRT neck and passing through the centerline of the tube to exit the left side of the neck. It was terminated with a 125 ohm load. An opening in center portion of the coaxial shield allowed the electron beam to pass through the transmission line close to the center conductor which became the active deflection "plate". An additional electrode nearby was the opposing deflection plate and provided vertical positioning with an applied DC voltage. A following grid shown in the basing diagram (Figure 7) probably was a mesh on the beam exit side of the structure to control the strong field from the subsequent 24.11 kV final accelerator to minimize pattern distortion. Jim Richardson, a retired Tektronix CRT engineer, recalls the T519C being referred to as the "knife edge tube". This was likely due to the fact that the center coaxial wire that provided vertical deflection made a very short deflection "plate" compared to conventional deflection systems. Transit time past the wire would be very short for fast response.

The T519C paragraphs have been reconstructed from the T5192 tentative data sheet and the memories of several retired Tektronix employees. The electrode configuration deduced above may not be exact, but until one of the tubes is examined or an old drawing surfaces, it will have to suffice. In any event, it should be fairly accurate.

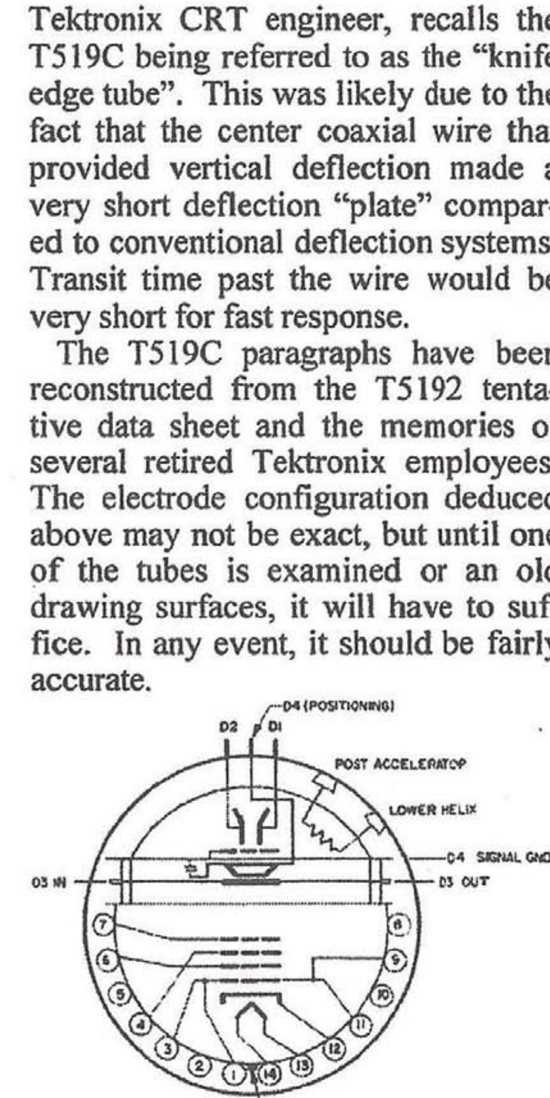

Fig. 7. T5192 basing diagram

T945

Also in 1961, the Model 945 oscilloscope was introduced. The 945 was a ruggedized and enviromentalized

TYPE	P1	P2	P7	P11	P16	P19	P20	P31	P32
T321	154-293	154-226	154-294	154-295				154-347	154-385
T503	154-264	154-265	154-266	154-267	154-318	154-311		154-341	154-387
T519 (Early)				154-356					
T519 (Late)				154-308					
T581	154-228	154-224	154-229	154-230	154-335		154-297	154-354	154-395

Table 1. CRT Part Numbers

version of the 545A for the military. It appeared only in the 1961 and 1962 instrument catalogs. The T945P2 CRT was listed in the catalogs as standard but no other information using that designation has been unearthed so far. It was basically just a militarized T543P2. By 1968, the T945 was designated T5431. The CRT data sheet for the T5431 dated April 19, 1968 describes it as follows:

> "The Tektronix Type T5431 is an aluminized 5-inch flat-faced cathode-ray tube with electrostatic focus and deflection and a helical post-accelerator. The tube features faceplate shielding to prevent radio interference; provisions for use at high altitude, over wide temperature ranges, and in high-humidity and fungus environments; and a ruggedized structure to withstand vibration and shock. The T5431 is designed to meet the applicable portions of Mil-T945A environmental specifications. The T5431 was designed for use in the Tektronix Type 945 Oscilloscope."

No Tektronix part number has been found for the T945 per se. A 1972 parts reference table lists the T5431P2 as p/n 154-0501-00 and the T5431P11 as p/n 154-0501-01. Both were listed as stocked for Customer Service only since the 945 was a discontinued instrument by then.

COMING NEXT

The next article in this series will discuss more of the innovative CRTs introduced by Tektronix during the early 1960s. Also to be discussed will be other CRTs used to expand the product line to cover diverse customer requirements.

REFERENCES

Keller, Peter A., The Cathode-Ray Tube, Palisades Press, 1991.

Griffiths, Stan, Oscilloscopes, Selecting and Restoring a Classic, 1992.

Lee, Marshal M., Winning with People: The First 40 Years of Tektronix, Tektronix, 1986.

Tektronix instrument catalogs.

Tektronix internal publications of instrument / CRT/part number cross reference lists, 1962-1989.

Chuck DeVere, Cathode-Ray Tubes, Tektronix Circuit Concept series, 1967.

Tektronix, Cathode-Ray Tubes: Getting Down to Basics, 1985.

TEKTRONIX CRT HISTORY
Part 5. The Hybrid Years: 1961-1964

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Part 1 described the situation leading to the decision in 1951-52 for Tektronix to begin design of cathode-ray tubes for its own use. Part 2 discussed the development of the first Tektronix CRT, the T51, in two different versions. Part 3 covered the classic Tektronix vacuum-tube oscilloscope CRTs during the period of about 1955 to 1959. Part 4 covered the innovative period from 1959 to 1961. This installment discusses more innovative CRTs for the first Tektronix storage oscilloscope and several other instruments using hybrid technology, which combined solid-state circuitry with the tail-end of vacuum-tube technology. At this time, there were still a number of functions that could be performed better and/or cheaper with vacuum tubes.

A few early semiconductors, particularly diodes, gradually began to be employed before this time period for some functions to save power consumption, reduce heat, and save space. This trend greatly accelerated during the early 1960s, as more reliable and higher performance semiconductors became available in production quantities.

CERAMIC ENVELOPES

Among the many advances in CRT technology during this time period was the development of the ceramic envelope (also referred to as a funnel) pioneered by Tektronix in 1961. Until then, CRTs were traditionally constructed using glass or metal envelopes. The unique Tektronix ceramic envelope was first developed in 1961 by William Wilbanks et al. (US Patent 3,207,936) and was applied with particular success in 1963 to the five-inch rectangular T5640 storage tube discussed below. Several reasons have been expressed for the use of ceramic rather than glass for the funnel. These include better utilization of excess capacity of the Tektronix ceramic plant, used to manufacture ceramic terminal strips, which were becoming obsolete as printed circuits came into use; lower cost; the ability to produce new shapes and sizes rapidly and relatively inexpensively; the ease of making the multiple electrical contacts necessary for storage tubes; the ability to fabricate designs that are impossible with glass; high shear and tension strengths; and reduced dependence on outside glass vendors and their occasional labor disputes. In all probability it was the combination of several of the above that prompted the use of ceramic envelopes. The use of ceramic was practical for CRT production runs of just a few hundred funnels per year, whereas the glass companies tended to require a few hundred thousand per year to justify tooling. A side benefit was that it became possible to print higher visibility internal graticules on the separate plate-glass faceplates used for the screens of ceramic CRTs. This faceplate was frit-sealed to the ceramic envelope, using techniques developed by the color picture-tube industry. Ceramic CRTs have been produced in many sizes and shapes, from the two-inch T2110 to the eleven-inch T6110 and many of the best selling Tektronix CRTs were converted to ceramic envelopes. Eventually, all later-designed Tektronix CRTs smaller than 11-inch used ceramic envelopes produced in-plant.

RECTANGULAR SCREENS

Also during this period of time, rectangular screens became the norm for laboratory oscilloscopes. A few basic rectangular screen CRTs became available during the 1950s, around the time that rectangular picture tubes displaced round tubes for television. Other than a few tubes of relatively low volume, the rectangular oscilloscope CRT did not displace the round tube overnight as it had in television.

The rectangular CRT offered two advantages. First, it made smaller oscilloscopes possible, which became a matter of greater importance in the 1960s as solid-state electronics displaced the vacuum tube and, second, scan was often limited in newer CRTs as a trade-off for bandwidth and deflection sensitivity. High-sensitivity round tubes had large wasted areas at the top and bottom of the screen which the electron beam could not reach. The first rectangular-screen CRT at Tektronix was the non-registered T503RS in 1962, which later evolved into the T5031 and T5032. Tektronix soon after began to use the rectangular screen in almost all new instrument designs, even those using a spiral accelerator, by use of a cylindrical portion of the funnel containing the helix which gradually changed to a rectangular cross-section near the screen.

INTERNAL GRATICULES

It was very difficult to make accurate measurements from the screens of the older blown-glass curved-face CRTs due to parallax between the scale or "graticule" overlay because of the non-uniform distance between the graticule and the phosphor plane. The flat-face tube had greatly improved the situation; however, the spacing between the plane of the graticules, which was usually illuminated, and that of the phosphor - due to the thickness of the glass faceplate between - still resulted in parallax errors and the resulting difficulty of having the eye lined-up in the same relative position for each measurement. Hewlett-Packard overcame this, beginning with their model 120-B oscilloscope in 1961, by forming the graticule internally on the glass faceplate before applying the phosphor screen. A finely ground black-glass powder which was fused to the glass faceplate was used to withstand the acid rinses and high-temperature baking associated with CRT processing. The only drawback of this graticule was the difficulty of photographing the graticule and the display simultaneously, since the black lines would not show unless backlit with "flood" electrons or the entire screen was illuminated with ultra-violet light to silhouette the graticule. H-P used both techniques. In 1964, Tektronix introduced illuminated, titanium dioxide, photo-deposited internal graticules, which allowed the use of conventional incandescent edge-lighting like that used for external graticules. A plexiglass combination light-pipe and implosion shield was laminated to the CRT faceplate to conduct the light to the graticule markings. The use of a separate faceplate frit-sealed to the funnel in the early 1960s allowed a considerable improvement in the visual appearance of the graticules. It lent itself well to the application of screen-printed, illuminated graticules using colored frit applied to the inner glass surface.

T310

The T310 was merely a Tektronix-produced version of the purchased 3WP- used in the 310A oscilloscope and 360 indicator unit. Improved quality and tightened specs, not cost, were likely the reasons for Tektronix to develop it, since the purchased 3WP-s were produced by several competing companies in fairly large quantities. Physically, the T310 had a larger neck diameter and longer phenolic base than the 3WP-. The T310, soon to be redesignated T3100, was available with P31 phosphor as standard and P1, P2, P7, P11, and P32 optionally.

T503RS/T5031

The RM561, a rack-mount version of the 561, used a space-saving rectangular version of the T503 that had been used previously in the Models 560 and 561. The acceleration voltage was 3.5 kV with no aluminizing or internal graticule.

The T503RS was normally supplied with P31 phosphor, and P1, P2, P7, P11, and P32 were cataloged as options. It soon became the type T5031 as the four-digit CRT numbering system took hold.

T561/T5610/T5032

The first ceramic-envelope CRT was the rectangular T561 (Figure 1) introduced in 1962 for the model 561A oscilloscope. It was lightly aluminized for improved brightness and operated at 3.5 kV. An illuminated internal graticule was standard.

The T561 was normally supplied with P31 phosphor, while P1, P2, P7, P11, and P32 were cataloged as options. The T561 became the T5610 and, in January 1965, was discontinued with the all-glass T5032 (Figure 2) replacing it.

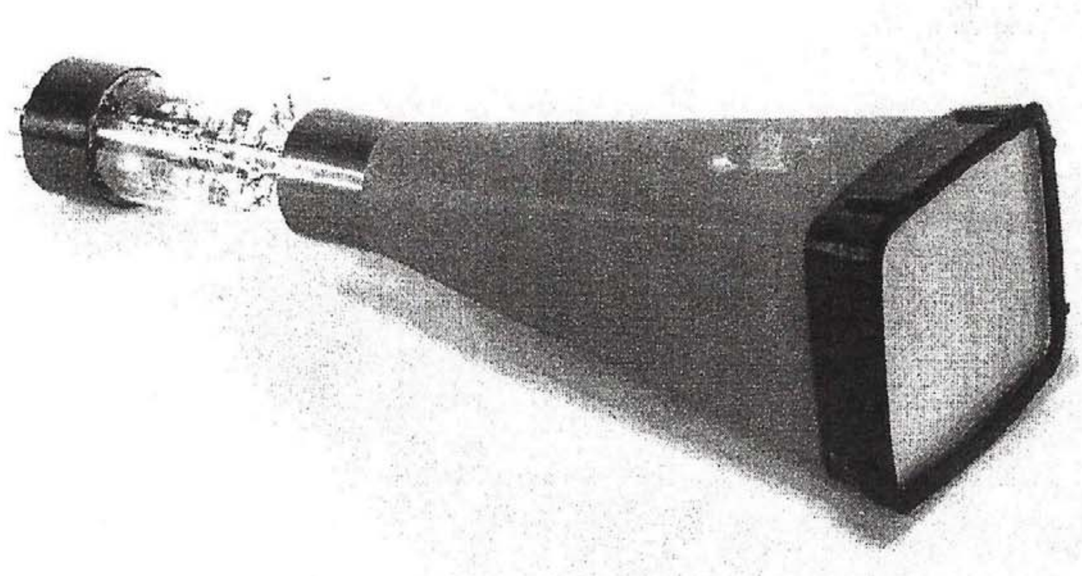

Fig. 1. T5610

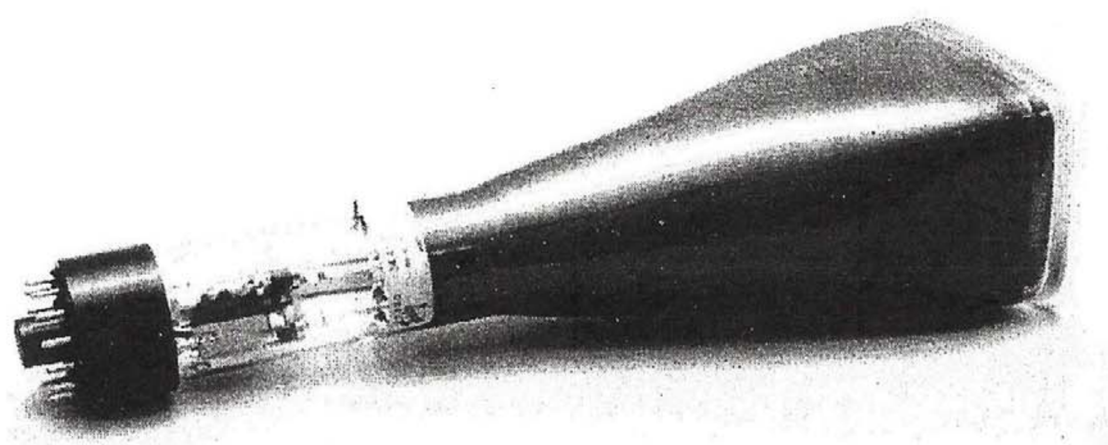

Fig. 2. T5032

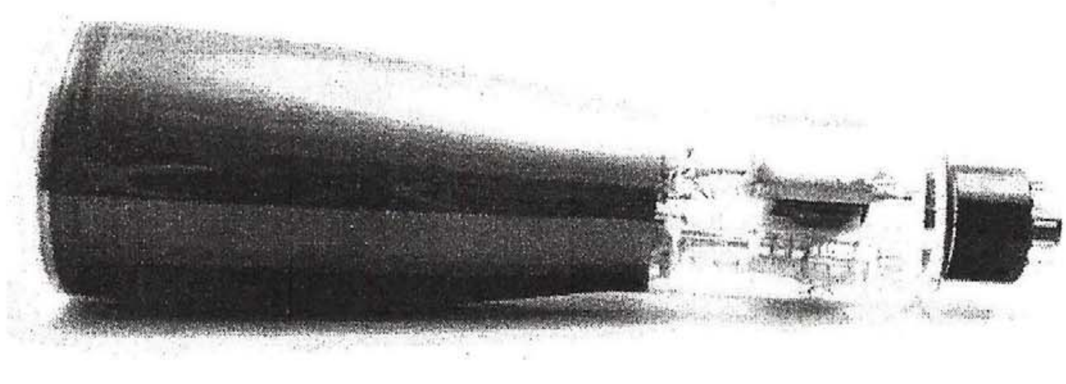

Fig. 3. T565

T565/T5650

The dual-gun, round, glass T565 (Figure 3) was essentially two T503s in one envelope. It was used only in the Model 565 and RM565 oscilloscopes introduced in 1962. An acceleration potential of 4 kV was used with no aluminizing and, at introduction, no internal graticule.

The T565 became the type T5650 in the new CRT numbering scheme. Illuminated internal graticules were added in 1965. P2 phosphor was standard, with P1, P7, P11, and P31 available on special order.

T5640

The Model 564 storage oscilloscope introduction was the big event of 1963 for Tektronix. Until then, the Hughes oscilloscopes using their Memotron storage CRT were about the only option for applications requiring viewing of low-frequency repetitive waveforms or single-shot events. The Memotron was easily damaged, expensive, and not particularly easy to operate. The simplified, bi-stable, direct-view storage tube (DVST) was invented by Robert Anderson at Tektronix in the late 1950s. Much effort was devoted over the next few years to making it a practical device and a commercial success. Unlike the fragile magnesium-oxide (MgO) coated storage mesh of the Memotron, the DVST used the phosphor screen itself to store the charge pattern of the displayed waveform. Both devices employed the secondary-emission characteristics of the MgO or phosphor respectively to store the charges. The high-voltage writing gun deposited the charges while the low-voltage "flood" guns maintained the charges in equilibrium until the user initiated erasure. Erasure of the screen involved suddenly raising the flood gun voltage to overwrite the entire screen, followed by a rapid drop in voltage to near-zero and gradual return to the "ready-to-write" voltage.

The Model 564 used the T5640 storage CRT. Other than the CRT and associated circuitry required for the storage functions, it was mechanically and electrically similar to the 561A and used the same series of vertical and horizontal plug-ins. The screen used P1 phosphor due to its similarity in secondary-emission characteristics to MgO and good visual properties. The phosphor was deposited as a decal on a flat glass faceplate having a transparent conductive film of tin oxide just under the phosphor. Voltages applied between this layer and the flood-gun cathodes established the ready-to-write and erase conditions of the screen. Additionally, the conductive film was split horizontally in the center of the screen to form two distinct screen areas that could be written and erased together or separately to allow comparison of two waveforms. The glass faceplate was frit-sealed to a ceramic funnel (Figure 4). Here, the ceramic envelope facilitated the forming of several conductive gold wallbands that comprised the collimation system used to control the uniformity of flood electrons at the screen. Each wallband had a separate conductive feedthrough connection to the outside of the funnel. From those points conductive silver stripes extended to the rear, where contact to the flood gun control circuitry was made with phosphor-bronze springs.

The electron gun was similar to that of the T561 except for the addition of two flood guns which were mounted near the deflection plates with their central axes inclined to point at screen center. The accelerating voltage was 3.5 kV. Aluminizing was not used, since low-voltage flood electrons would be unable to penetrate it. There was some loss of brightness compared to the T561, since the screen thickness and density were optimized for their storage characteristics. The tin-oxide layer also absorbed some light from the phosphor. Still, it was an excellent compromise for both storage and conventional applications. With the phosphor in good thermal and mechanical contact with the glass faceplate, it was very rugged and not easily burned through misuse. Conversely, the Memotron with its coating of MgO for storage on a fine mesh mounted behind the phosphor screen was easily damaged.

Two versions of the T5640 were available. The first, intended for general use, used just P1 for the screen decal. The tube designation was T5640-200. The second contained a few percent of MgO added to the P1 phosphor, which improved the sec-

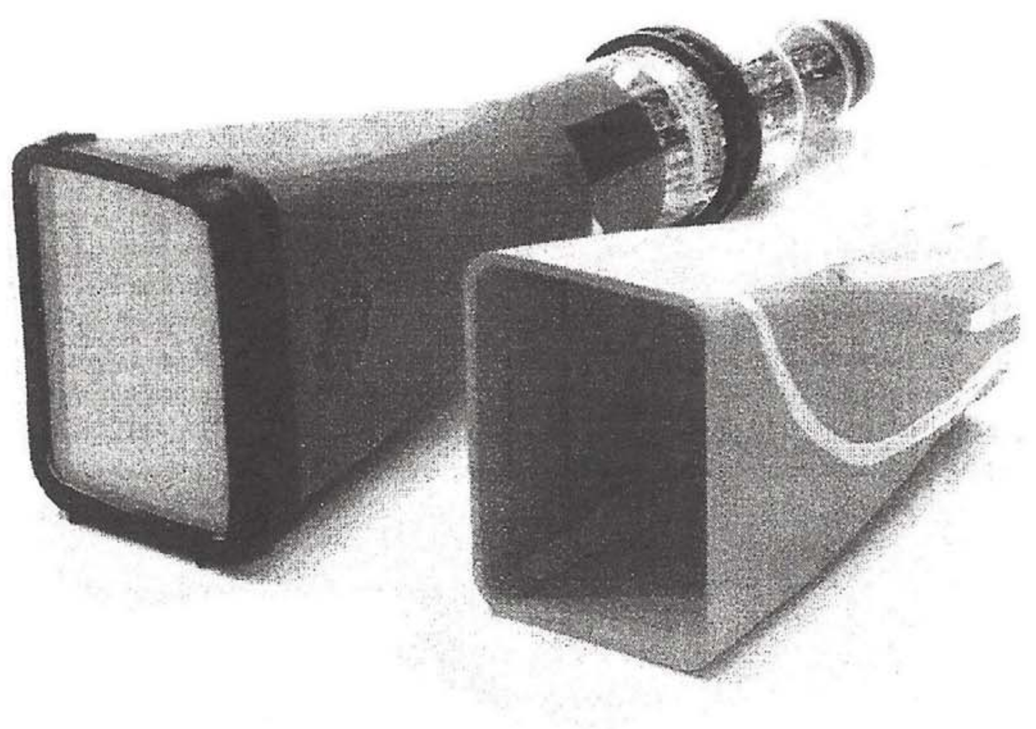

Fig. 4. T5640 storage CRT and ceramic envelope

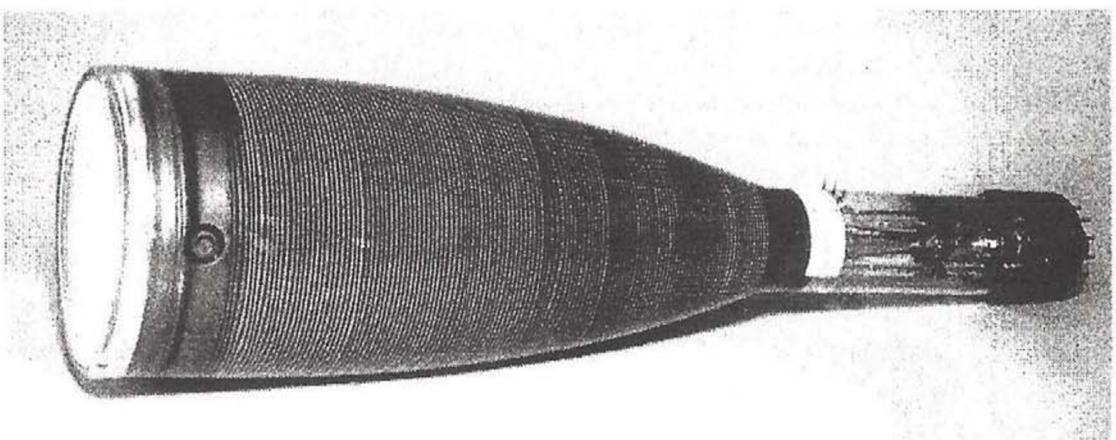

Fig. 5. T5470

TYPE	P1	P2	P7	P11	P31	P32
T310	154-0362-00	154-0363-00	154-0364-00	154-0365-00	154-0366-00	154-0382-00
T503RS	154-0319-00	154-0320-00	154-0321-00	154-0322-00	154-0355-00	154-0388-00
T5031	154-0319-00	154-0320-00	154-0321-00	154-0322-00	154-0355-00	154-0388-00
T5032		154-0454-00	154-0455-00	154-0456-00	154-0449-00	
T5470 Early		154-0450-00	154-0451-00	154-0452-00	154-0429-00	
T5470 Later		154-0478-01	154-0478-02	154-0478-03	154-0478-00	
T561	154-0396-00	154-0397-00	154-0398-00	154-0399-00	154-0400-00	154-0401-00
T565	154-0357-00	154-0358-00	154-0359-00	154-0360-00	154-0368-00	
T5650 Early		154-0426-00	154-0439-00	154-0440-00	154-0441-00	
T5650 Later		154-0477-00	154-0477-01	154-0477-02	154-0477-03	

Table 1. CRT part numbers

ondary-emission characteristics for higher writing speed. The tradeoff was lower brightness. It was designated T5640-201. The DVST was a resounding success. It ultimately led to a series of data terminals, desk computers, and data displays with screen sizes up to 25".

T5470

In the author's opinion, the T5470 CRT (Figure 5) and its associated instruments, the 543B, 544, 545B, 546, and 547, comprised the finest of the classics. This series of instruments began in 1964 as replacements for the 540-series scopes that had become the leading instruments in the Tek product line. They featured a very fine spot-size (under 10 mils), 50-MHz bandwidth, hybrid circuitry, illuminated internal graticule, and larger 6-by-10-cm scan area, while retaining the familiar appearance and layout of the 530/540-series instruments. This resulted in an instrument by which all others are often judged by those of us who spent many hours working with them.

The T5470 was a long CRT, over 20" overall, using the same bulb as the T581/T5810. Segmented, narrow vertical deflection plates similar to those of the T581, but without the delay line, achieved good vertical deflection sensitivity with low capacitance for wider bandwidth. The acceleration voltage was 10 kV. Development of this series was forced by competitive pressure from the entry in the oscilloscope market by Hewlett-Packard, with their Model 175-A having many of the same features. The latter suffered from the unfamiliar panel layout, poor spot size, and the feeling prevailing in the market by then that if you wanted the best, Tektronix was *the* oscilloscope to buy. It had become the status symbol for the engineer.

P31 aluminized screens were standard in the T5470 but P2, P7, and P11 were available as options. The 5-inch, round, glass T5470 soon evolved into the similar T5471 which used a ceramic envelope. We extensively used 547 scopes and many T5470s built in the Engineering Tube Lab to evaluate phosphors, screen processing, and internal graticule designs during the 1960s.

Note: By early 1965, the T#### type numbering and nine-digit part numbering systems were fully in place. Many of the CRTs discussed in this article were popular for several years. Custom internal graticules and other variations resulted in too many part numbers to be completely described here. By 1968 internal graticules were designated in the tube type by a single digit following the phosphor type. Also, the "P" preceding the phosphor type was dropped. Thus a T5032 with P31 phosphor and standard 8-by-10-cm internal graticule became the T5032-31-1. The special internal graticules as well as the "no-graticule option" continued the proliferation of part numbers as well as tube type numbers. Also note the differences in CRT part numbering that occurred between the early and later T5470s and T5650s. The center four digits became the same for the basic tube type, with the two-digit suffix denoting the phosphor. The 154 prefix used for all CRTs remained the same. By this time, the availability of many phosphors on special order had begun to decline somewhat.

COMING NEXT

The final article in this series will discuss CRTs introduced by Tektronix during the mid-1960s for the beginning of the all-solid-state era (except for the CRT, of course).

REFERENCES:

Keller, Peter A., The Cathode-Ray Tube, Palisades Press, 1991.

Griffiths, Stan, Oscilloscopes, Selecting and Restoring a Classic, 1992.

Lee, Marshal M., Winning with People: The First 40 Years of Tektronix, Tektronix, 1986.

Tektronix instrument catalogs.

Tektronix, CRT Data Book, looseleaf binders, individual CRT data sheets updated as needed throughout the 1960s.

Tektronix internal publications of instrument / CRT/part number cross reference lists, 1962-1989.

TEKTRONIX CRT HISTORY
Part 6. CRTs for Solid-State Instruments: 1964-1967

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Part 1 described the situation leading to the decision in 1951-52 for Tektronix to begin design of cathode-ray tubes for its own use. Part 2 discussed the development of the first Tektronix CRT, the T51, in two different versions. Part 3 covered the classic Tektronix vacuum tube oscilloscope CRTs during the period of about 1955 to 1959. Part 4 covered the innovative period from 1959 to 1961. Part 5 discussed more innovative CRTs for the first Tektronix storage oscilloscope and several other instruments using hybrid technology, which combined solid-state circuitry with the tail-end of vacuum tube technology. This concluding article covers the beginnings of the solid-state era as well as one last unique hybrid model worthy of mention.

SCAN-EXPANSION MESH

Scan-expansion systems came into being in the early- to mid-1960s. At this time, transistors were taking over many circuit functions previously performed by vacuum tubes. One of the most difficult functions was the amplifier used to drive the deflection plates of the CRT. Large voltage swings, combined with the need for ever-increasing bandwidths, dictated the continuing use of tube in these stages. Tubes operated comfortably at plate voltages up to several hundred volts, while the emerging transistors might tolerate only 60 volts or less without permanent damage. Scan expansion provided magnification of the beam and deflection by shaping the electrostatic fields between the deflection plates and final acceleration region. Either a frame-grid which gave magnification for only the vertical axis or a domed-mesh (Figure 1), which magnified both axes, was used. The trade-offs included scattered secondary electrons from the grid mesh, which gave a dim ghost image, magnification of spot-size, contamination by loose foreign particles in the tube,

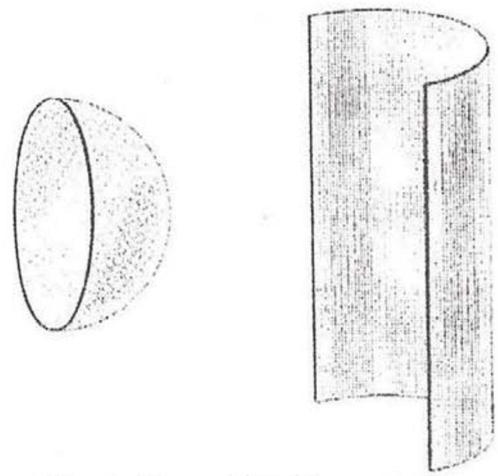

Fig. 1. Domed and frame-grid scan-expansion mesh

greater assembly complexity, lower production yields and higher cost. Still, scan expansion was a "must" in order to complete transistorization of the product line.

T6470

The T6470 (Figure 2) was used only in the 647 and RM647 oscilloscopes introduced in 1964. These were designed for the Royal Air Force and used a pair of special plug-ins: the 10A- series vertical amplifier and 11B- series horizontal timebase. The 647 was all solid-state and only about 2/3 the size of the ubiquitous 500-series oscilloscopes. The instrument was ruggedized for the severe operating environments of the military.

The T6470 CRT was rectangular, with the 3" by 5" screen dimension closely approximating the 6-by-10-cm useful scan area. The earliest instruments up to approximately serial number 560 used a ceramic CRT. This was changed to a glass version in December 1964, presumably because of manufacturing problems, possibly high voltage punch-through caused by contamination of the frit seal. The T6470 also featured an illuminated internal graticule, 14 kV accelerating potential, frame-grid mesh for greater vertical deflection sensitivity and a spiral accelerator. The latter presented some challenges, since painting the resistive helix on a rectangular envelope would be difficult. The problem was solved by having a flared, round transition section of the envelope between the neck and the larger rectangular portion. This resulted in a much shorter helix compared to previous tubes, where the helix extended almost the full length of the bulb. P31 phosphor was standard, with P11 available as an option for those customers requiring high photographic writing speed.

T4220

The Model 422 15 MHz dual-trace general-purpose portable oscilloscope of 1965 began the series of solid-state oscilloscopes that thrived until the end of CRT production at Tektronix in 1994. True, the Model 321 of 1960 was the first solid-state Tektronix scope, but it was more of a test bed for the concept and never became a best-seller. The 422 used a new horizontal form-factor with an adjustable carrying handle that also served as a tilt bail. This configuration evolved through the 453 and 454 to the 465 of the 1970s, probably the best-selling Tektronix oscilloscope family of all time.

The T4220 (Figure 3) was a compact, rectangular, all-glass CRT employing a scan expansion mesh for good deflection sensitivity despite the short length. Also contributing to the shortened length was the first use of the "hard-pin" stem or base. Instead of the conventional bakelite base, the T4220 used a glass header with heavier, short feed-through leads that were used as the connecting pins, as had been in use for over 20 years for miniature receiving tubes. A plastic base guide provided indexing and protection of the exhaust tip-off seal in the center of the pin circle. An accelerating voltage of 6 kV, combined with P31 as standard phosphor, resulted in a bright display even in adverse ambient environments. A short spiral accelerator was located in the circular transition area from the neck to the rectangular funnel. The screen had an illuminated internal graticule with 8 by 10 divisions of 0.8 cm each. A two-watt heater, instead of the customary four-watt heater, was used to reduce power consumption for battery operation. By this time, phosphor choices had been reduced to P1, P2, P7, P11, and P31, which helped the proliferation of part numbers to some degree.

T4530

The 453, introduced in 1966, brought lab instrument performance to the portable oscilloscope. It had 50 MHz vertical bandwidth with dual trace and delayed sweep capability in a rugged and compact design. It was useful for most things that a 547 would do with well under half the weight and volume. Power consumption was only 100 watts compared to 510 watts for the 547. The useful screen area was still 6 by 10 divisions but the divisions were only 0.8 cm instead of the traditional 1 cm.

The T4530 CRT (see Figure 5 below for the similar-appearing T4540) looked somewhat like a stretched T4220. Like the T4220, it also used a scan expansion mesh, hard-pin base, spiral accelerator, and illuminated internal graticule. All of these defined state-of-the-art CRTs for some time to come. An acceleration voltage of 10 kV was used for high photographic writing speed. P31 phosphor was standard with P1, P2, P7, and P11 available as options.

T5490

In 1966, the final instrument in the revered 530 / 540 series of instruments was introduced. It was the Model 549 storage oscilloscope and used the T5490 CRT. The 549 was something of an ugly brute. It combined an improved storage CRT for the 30-MHz bandwidth and plug-in compatibility of the older 540-series instruments. The physical size and layout were pretty much in the tradition of the 530 / 540-series, although the screen was lowered, with the storage controls located just above it. A rectangular bezel was used to mask the unusable portions of the screen. Because of the performance trade-offs required to add storage capability, the 549 never achieved the popularity of its predecessors.

The T5490 CRT used a round screen and ceramic envelope (Figure 4). The basic operating principle was the same as in the T5640 DVST discussed in Part 5 of this series. To obtain higher stored writ-

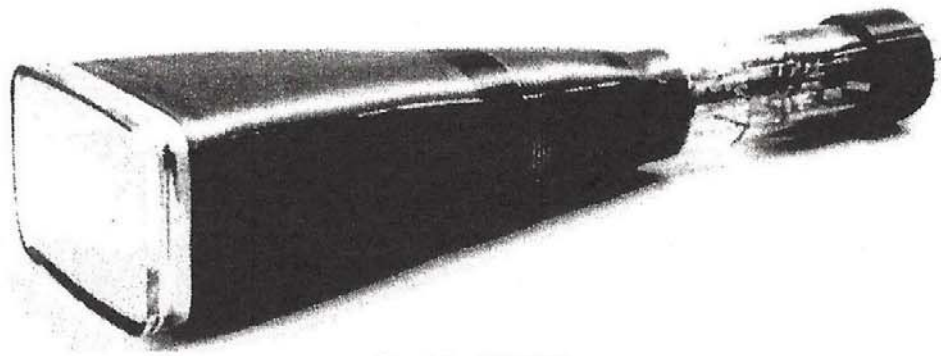

Fig. 2. T6470

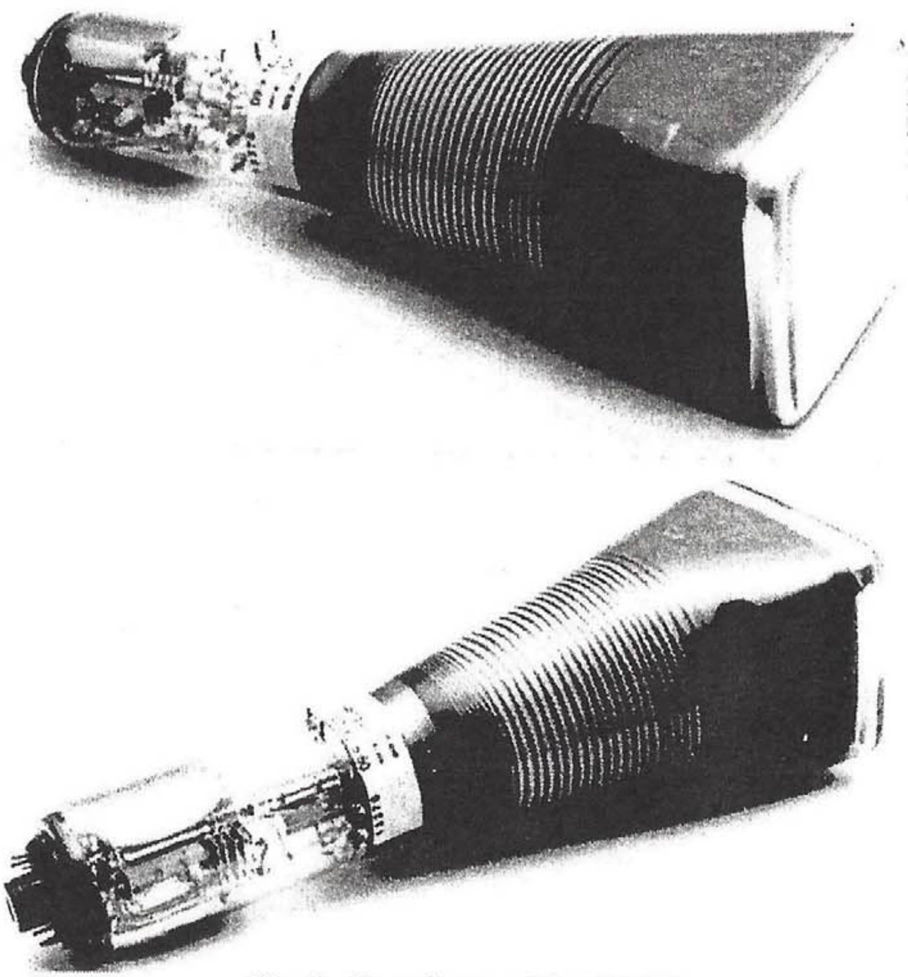

Fig. 3. Two views of the T4220

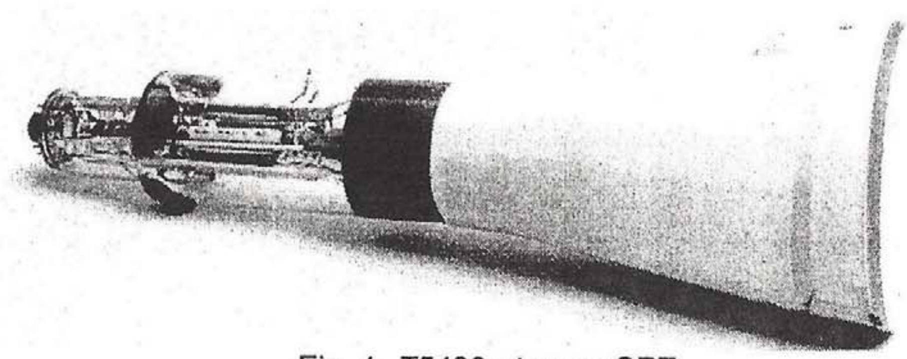

Fig. 4. T5490 storage CRT

ing speed suitable for the instrument's wider bandwidth, a more complex screen (or "target") structure designated Type 202, and consisting of closely-spaced hexagonal dots of P1 phosphor, was used. This left exposed conductive areas surrounding the dots, which aided collection of secondary electrons and resulted in about ten times the stored writing speed of the T5640-201. Unfortunately, the T5490-202 lacked the high brightness of the original 540 series in the conventional operating mode. This was due to several factors. The accelerating voltage was only 4 kV, compared to 10 kV; the screen could not be aluminized; the P1 phosphor was not as bright as P31; the exposed collector area decreased the screen area covered by phosphor and contributed no light; and MgO added to the phosphor for improved writing speed further decreased light produced by the phosphor. The phosphor layer may also have been thinner than used for conventional screens that had thicknesses optimized for brightness. An external illuminated graticule was used, since it would have been very difficult to add it to the already complex screen structure. No optional phosphor types were ever available as options since it was the unique secondary-emission properties of P1 that made the simplified storage CRT work in the first place.

T4540

The 454 was merely a 453 with the vertical bandwidth extended to 150 MHz in keeping with the trend towards ever-increasing needs for higher frequency design work. The 453 debuted in 1967.

The T4540 CRT (Figure 5) differed from the previous T4530 primarily in its use of a distributed vertical deflection-plate system in order to achieve 150 MHz bandwidth with good deflection sensitivity. The same phosphors were available as in the T4530.

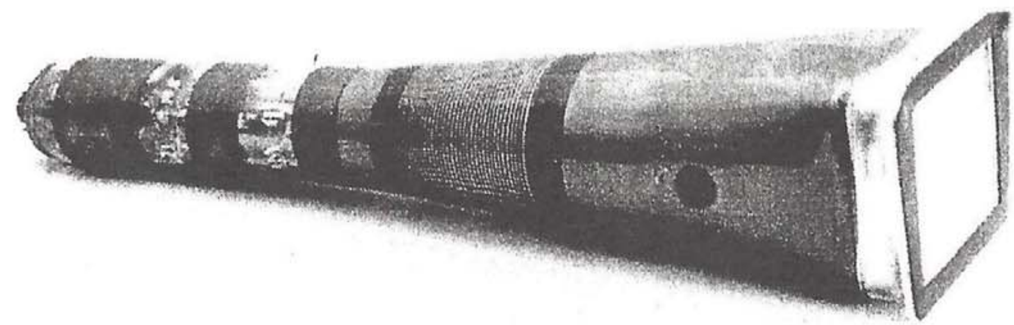

Fig. 5. T4530

TYPE	P1	P2	P7	P11	P31
T4220 Early	154-0466-01	154-0466-02	154-0466-03	154-0466-04	154-0466-00
T4220 Later	154-0466-06	154-0466-07	154-0466-08	154-0466-09	154-0466-05
T4530	154-0492-00	154-0492-01	154-0492-00	154-0492-00	154-0492-00
T4540	154-0505-01	154-0505-02	154-0505-03	154-0505-04	154-0505-00
T6470 Early					154-0424-00
T6470 Late				154-0434-00	154-0448-00

Table 1. CRT Part Numbers

CREDITS

I would like to acknowledge the many CRT design engineers, scientists and others at Tektronix who made possible the significant advances discussed in these articles. The author worked with many of them from 1963 on. Any omissions are due to faulty memory caused by forty to fifty years of elapsed time. These "Tekies" include:

Continued from p. 16

Robert Anderson	Chuck Gibson	Bill Mason	Ron Robinder
Mel Balsinger	Joe Griffith	Ernst Massey	Johnnie Schmauder
Gordon Barnett	Bob Guthrie	Dick McMillan	Larry Simpson
Bill Beran	Dennis Hall	Joe Merz	Ed Srebnik
Bill Brown	George Hashizume	Ralph Mossman	Bruce Steller
Marlow Butler	Jim Hawes	Jack Neff	Ken Stinger
Larry Caufield	Ken Hawken	Bob Nelson	Lloyd Swedland
Dick Coovert	Jim Helmer	Orv Olsen	Pete Unger
Chris Curtin	John Hutcheon	Derrol Pennington	Larry Virgin
Ken Davis	Phil Johnson	Pete Perkins	John Whitesides
Jean DeLord	Robert Johnson	Morgan Pope	Connie Wilson
Jim Donoghue	Don Kephart	Roy Record	Alan Yielding
Egon Elssner	Bela Kirchberger	Jim Richardson	

This concludes the series of articles about CRT innovations developed and used by Tektronix in many of the "classic" oscilloscopes. Many more milestone CRTs were developed in subsequent years. These are covered in my book, The Cathode-Ray Tube, and are outside the scope of this series.

REFERENCES:

Keller, Peter A., The Cathode-Ray Tube, Palisades Press, 1991.

Griffiths, Stan, Oscilloscopes, Selecting and Restoring a Classic, 1992.

Lee, Marshal M., Winning with People: The First 40 Years of Tektronix, Tektronix, 1986.

Tektronix instrument catalogs.

Tektronix, CRT Data Book, looseleaf binders, individual CRT data sheets updated as needed throughout the 1960s.

Tektronix internal publications of instrument / CRT / part-number cross-reference lists, 1962-1989.

Chuck DeVere, Cathode-Ray Tubes, Tektronix Circuit Concept series, 1967.

Tektronix, Cathode-Ray Tubes: Getting Down to Basics, 1985.