Tektronix Type 545 Oscilloscope
Calibration and Maintenance Procedure

Type 545 Oscilloscope

CALIBRATION AND MAINTENANCE PROCEDURE

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Edition B

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Changes:

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Abbreviations		Revised	5-62
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Calibration & Maintenance Procedure

070-282

Supplement

May, 1962

The enclosed pages contain revisions and corrections to the Tektronix Type 545 Calibration and Maintenance procedure Edition B. Remove and destroy old pages. You may already have revised page 3-30 (Rev 8-61) -- if so, you may throw away the copy enclosed.

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ABBREVIATIONS

C.F. or cf	Cathode-Follower
CRT	Cathode-Ray Tube
CW	Clockwise
CCW	Counterclockwise
D.S. or Del'g Swp	Delaying Sweep
D.A. or DA	Distributed Amplifier
Ext	External
HV	High Voltage
Int	Internal
kc	Kilocycle (10^3 cycles)
k	kilohm (10^3 ohms)
M.S.	Main Sweep
μf	microfarad (10^{-6} farad)
μμf	micro-microfarad (10^{-12} farad)
μsec	microsecond (10^{-6} second)
mc	megacycle (10^6 cycles)
mm	millimeter (10^{-3} meter)
msec	millisecond (10^{-3} second)
mv	millivolt (10^{-3} volt)
M.V.	Multivibrator
nsec or mμsec	Nanosecond or millimicrosecond (10^{-9} second)
Ω	Ohms
p/n	Part Number
p-p	Peak-to-Peak
pf or μμf	Picofarad (10^{-12} farad)
RMS	Root-mean-square
S/N	Serial Number
Spec	Specification
Trig	Trigger
V.A. or VA	Vertical Amplifier
v	Volts

(Revised 5-62)

SECTION 3

CALIBRATION AND MAINTENANCE PROCEDURE

0 GENERAL INSTRUCTIONS

0.1 USING THE PROCEDURE: As far as possible, each step in this procedure is divided into three main parts: Measurement, Adjustment, and Trouble-shooting. The calibrator needs only to proceed within the step far enough to secure specified performance, and may skip the remaining portions.

0.2 TROUBLESHOOTING: The troubleshooting procedure normally is arranged in order of probable causes: These should be checked out in the order given. In a few cases, involving high-value or hard-to-replace components, procedures are arranged as a process of elimination.

0.3 CAUTION: Steps are arranged to minimize interaction effects and the necessity for "backtracking". Any trouble-shooting should always start with a check of the power-supplies, and a complete recalibration should always follow the indicated order so that calibrations made first are not thrown off by later adjustments.

0.3.1 Example: Adjusting the low or high voltage power supplies after calibrating the sweep or vertical will require a complete recalibration of both sweep and vertical.

0.4 USING THE CALIBRATION RECORD AS A GUIDE: After the calibrator has become familiar with the attached procedure, the Calibration Record Section 4 can become his primary guide for a complete calibration, and only occasional reference need be made to the more detailed and involved test of the procedure.

0.5 ENTRIES IN THE CALIBRATION RECORD: Three types of entries are indicated for the Calibration Record (Section 4) ("Cal Record") in the procedure. "Note" generally indicates the calibrator should enter "good" "fair" "poor" "OK" "NG" or other appropriate comment in the space provided. "Check" usually calls for simply marking the record to indicate the performance of a step. "Log" calls for the recording of some specific figure (voltage, time, error, dial setting, etc.) in the appropriate space. In addition to the entries called for in the procedure, all parts replaced during calibration and troubleshooting, (perhaps with an indication of the defect), should be recorded in the right hand margin in the spaces provided. Generally they can be identified by their schematic symbol (e.g., V20, V58, R265, etc.).

An index to Section 3 will be found on the reverse of this page.

SECTION 3

INDEX

7.1.3 Cathode Interface Check: Install Type (53/54) P Plug-in and pre-set front-panel controls as follows:

Stability	Triggerable	Horizontal Display	Main Swp Norm.
Triggering Level	0	Trigger Slope	+Int
Time/Cm	.1 μsec	Triggering Mode	AC Fast
Multiplier	2	Coil Current	On
Magnifier	Off	Amplitude	3 O'clock

Install viewing hood. Adjust Triggering Level control for stable display with trigger-point about 1/2 cm ahead of rising portion of waveform (See Fig 7-2). Adjust Amplitude control for about 3 cm display, and position leading edge near center of graticule.

7.1.3.1 Driver Stage Check: Examine the waveform for a sharp dip immediately following the leading edge (See Fig 7-3), indicating possible defect in driver-stage tubes. Adjust line voltage to 105 v for 10-15 seconds, then to 125 v. If the "notch" appears to change amplitude with changing line voltage, try replacing the driver stage tubes (in early instruments, V1050 and V1052; in later instruments above s/n 9291, V1033 and V1043). Return line voltage to 117 v.

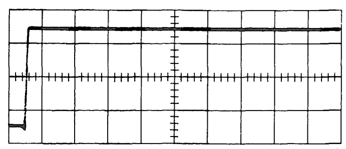


Fig. 7-2 P Unit Display at 0.2 μsec/cm.

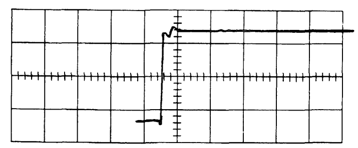


Fig. 7-3 Effect of defective driver-stage tubes, 0.2 μsec/cm.

7.1.3.2 Input Stage Check: Reduce sweep speed to 0.5 μsec/cm. Examine waveform for slope in first cm following leading edge (Fig. 7-3). Check for effect of line-voltage change on slope. If line-voltage affects slope, try replacing input amplifier tubes (6AW8's or 12BY7A's) with aged and checked tubes from same subgroup. If tubes are replaced, repeat Step 7.1.

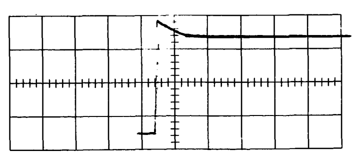


Fig. 7-4 Effect of "cathode interface" in V.A. 0.5 μsec/cm.

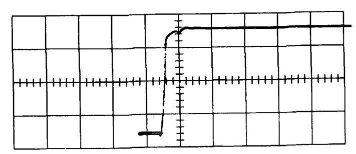


Fig. 7-5 Rolloff defect in D.A. tubes. 0.5 μsec/cm.

7.1.3.3 Distributed Amplifier Tube Defects: If tube replacement in 7.1.3.2 does not eliminate changes in slope (Fig. 7-4 or 7-5) with line-voltage change, distributed amplifier tubes (6CB6's or 6DK6's) will require replacement.

(Do not mix tube brands.) Use of 6DK6's is no longer recommended (SN 9292 - up). Replace with type 8136 (Tektronix p/n 154-367). See page 5-0.

Now, turn P-Unit "off". Center the trace and check voltage at each suppressor grid in the distributed amplifier for +175 v. Replace any tube which does not read at least 165 v at the suppressor grid. (If tube replacement does not correct voltage, check suppressor bypass capacitors.)

7.2 VERTICAL BALANCE:

NOTE: It will be necessary (where specified) to use a "resistive shorting bar", consisting of a 47-ohm 1/2 watt composition resistor attached to some convenient insulating handle, for shorting grids together. Use of clip leads or wires will introduce enough inductance to cause oscillation, usually at a frequency far beyond the amplifier bandpass. These oscillations are rectified in the amplifier and appear on the CRT as DC level changes, making balance measurements impossible. The resistor lowers the Q of the inductive circuit below the point where oscillations can occur.

7.2.1 Overall Balance: Free run the main sweep at 1 msec/cm or faster. Locate CRT electrical center by shorting the vertical deflection plate pins together (NOT to ground). Note graticule position of electrical center and remove jumper. Now position the trace back to CRT electrical center, using vertical position control.

Now, use the resistive shorting bar (if test load unit is used, press "zero reference" button) to jumper the main amplier input stage grids together. Connect the shorting bar between pins 1 and 3 of the plug-in interconnecting socket. Log trace displacement from CRT electrical center in Cal Record. If 1 cm or less, skip 7.2.2 for the moment (it may be necessary to come back to this later). If more, complete 7.2.2.

7.2.2 Vertical Balancing:

7.2.2.1 Distributed Amplifier Stage: Use a short cliplead to jumper the distributed amplifier grid lines together (the two distributed lines running outside the rows of tube sockets, connecting with pins 1 of the DA tubes).

(CAUTION: Do not short to ground).

If trace-shift from electrical center is 2 mm or less, log in Cal Record and proceed with 7.2.2.4. If more , complete 7.2.2.2-7.2.2.3.

7.2.2.2 D.A. Bias: Again jumper DA grid lines. Use DC voltmeter to measure grid-to-cathode bias for each tube pair. For each pair, measure from jumper to either cathode (pin 2) of each pair. For S/N 101-9291 (and 9292-11691 with original tubes*) bias should be 0.9-1.6 volts. For later instruments, 1.0 v minimum to 2 v max. Replace one or both tubes of each out-of-tolerance pair. For S/N 101-9291, use checked 6CB6's, Tektronix p/n 157-037. For S/N 9292-up, select "raw" Type 8136's but see* below. Log high and low bias values in Cal Record.

*6DK6 design changes in late 1958 require modification of instruments S/N 9292-11691 to use the new-style tubes. Modification kit 040-191 ($1.80) changes cathode resistors in the 12BY7 stage to provide 1.0 v minimum bias on output stage, and permits use of old or new 6DK6's or 8136's. To check doubtful instrument, examine R1016 & R1017--if 3k (5w5%) and 10 k (8w 5%), the instrument has already been modified. For discussion of type 8136 tube, see page 5-0.

7.2.2.3 D.A. Balancing: After selection of tubes (if necessary) for proper bias, recheck 7.2.2.1. If trace shift is still greater than 2 mm from CRT electrical center, tubes of a pair can be "swapped across" to achieve balance. If tubes are swapped between pairs, or if further tube replacements are required for balance, repeat 7.2.2.2. Log final balance point, and reposition trace to this point.

If imbalance persists, check resistances of reverse termination network (plate loads) for symmetry (±2%). Check for opens or shorts in individual suppressor-grid networks, and for partial short to ground on one side of delay line.

TUBE REPLACEMENT NOTE: Do not reject 6CB6 or 6DK6/8136 tubes because of a slight blue glow (noticeable only in a darkened room) outside the plate area. This is not necessarily an indication of gas, but is caused by glass fluorescence where the envelope is struck by the accelerated electron beam, and is normal in good tubes. If in doubt, check tube in conventional gas-detection circuit. Tubes should not be rejected for heater-cathode leakage unless it is less than a few thousand ohms. These tubes normally show slight leakage.

7.2.2.4 Driver Stage Balancing: Use the resistive shorting bar to jumper the grids of the driver cathode-followers. Select tubes if necessary for not more than 1/2 cm trace shift from DA imbalance point. In instruments above S/N 9291, both cf stages must meet this specification. For optimum balance with minimum tube selection, use Type ECC88/6DJ8 or E88CC/6922 instead of Type 6BQ7A. If imbalance persists, check cathode resistors for symmetry (±10%), and check plate voltages, filament lines, etc.

7.2.2.5 Input Stage Balancing: Position trace to CRT electrical center, and again jumper input stage grids as in 7.2.1. Trace shift should be 1 cm or less. Install new checked input tubes (6AW8's p/n 157-039 or 12BY7A's p/n 157-053 -- See footnote, 7.1.2) if necessary. If imbalance is less than 1/2 cm from driver-stage imbalance point, but more than 1 cm from CRT electrical center, try swapping positions of the input tubes before replacing with new ones.

If input stage imbalance persists, check values of plate load resistors for symmetry; also cathode resistors. Check components in DC Shift compensation networks(tiny 68 k resistors connected to input stage plate loads, etc.).

7.3 LINEARITY: Install Dual-Trace plug-in. Free run main sweep at 10 µsec/cm. Position trace to top and bottom of visible scan. If necessary, remove graticule cover and use white nylon cam to adjust graticule so rulèd portion is exactly centered in area of usable scan.

7.3.1 Compression (linearity) Measurement: Set vertical Volts/Cm to 5, and display exactly 2 cm of calibrator waveform (adjust Variable volts/cm if necessary), centered vertically. Position the display up to the top graticule line and note any compression or expansion (Spec: 0.5 mm max). Now, position the display so it "rests" on the bottom graticule line, and note compression or expansion. If within spec, log measured figures on Cal Record.

7.3.2 Troubleshooting:

7.3.2.1 Compression at Top and Bottom; Expansion at Top and Bottom: Check to see if compression or expansion is the same at the edges of the graticule as at the center. If not, reset Geometry (6.3). If compression is uniform across CRT, recheck DA Bias (7.2.2.2) and CRT Deflection Factor (6.4.3-6.4.4). Recheck regulated power supplies (2.3), especially +350 v supply. Check DC level at pins 1 and 3 of plug-in connector for 67 ± 1 v.

7.3.2.2 Compression and Expansion: If trace shows compression in in one direction and expansion in the other, recheck vertical balance (7.2). Complete steps 7.2.2.1 through 7.2.2.5 if skipped before. If balance and bias are within tolerance, try swapping CRT Vertical deflection plate leads for inverted display. If directions of compression and expansion are reversed, trouble is in vertical amplifier. If they remain exactly as before, try replacing CRT, following procedures in 6.4. Try another plug-in.

7.3.2.3 Persistent Troubles: If CRT change does not correct trouble, try exchanging complete vertical tube complement from known-good instrument of same serial range. Check screen and filament circuits, vertical termination network, etc. Check for partial short to ground in delay line. For instruments S/N 9292-11691, check to see if modification kit 040-191 has been installed to accomodate new type 6DK6/8136 tubes. In modified instruments, R1016 and R1017 (in input stage cathode circuit) will be 3 k and 10 k respectively. See 7.2.2.2 and footnote. Install mod kit if necessary. In rare cases compression has been caused by a bad CRT shield. If all else fails, try installing a new shield.

7.4 D.C. SHIFT:

7.4.1 D.C. Shift Check: Use battery, or ohmmeter range of VOM to deflect free-running trace 4 cm. Watch trace closely for 5-10 seconds. If it drifts from its first stopping point, log amount and direction of drift in Cal Record under "Initial" (re-check measurement by noting drift during 5-10 seconds after removal of DC voltage). If this drift is 1/2 mm or less, proceed to 7.5. If more than 1 2 mm, complete 7.4.2.

7.4.2 D.C. Shift Compensation: Locate D.C. Shift Comp. control on main amplifier chassis. Repeat 7.4.1, making small adjustments of this control. D.C. shift itself is a slow decrease in deflection; over-compensation will result in a slow increase in deflection. Set compensation for as close to zero shift as possible. Recheck at slow (2 sec/cm) sweep. Log final shift and direction in Cal Record under "Final".

7.4.3 Troubleshooting: The D.C. shift compensation network consists of the small 8.2 k resistors connected to the terminated end of the output plate lines, the control itself, four 75 µf electrolytic capacitors, the two 47 k resistors between capacitor sections, and the small 68 k resistors connected to the plate load resistors of the input amplifier stage.

7.4.3.1 Inadequate Range of Control: Check the small resistors first for correct value: They are likely to be damaged by any severe power supply aberration. Check the electrolytic capacitors for leakage or change of value. See that there are no open spots in the control.

7.4.3.2 Trouble Not in Compensation Circuit: If all compensation network components are within tolerance, it may be necessary to replace vertical amplifier tubes. If these are replaced, be sure to repeat step 7.1, 7.2, and 7.3. Also recheck proper operation of regulated DC supplies and vertical amplifier filament circuits.

7.4.3.3 Wrong Time-Constant: (S/N 9292 and up): If new General Electric 6DK6/8136's are used and DC shift compensation appears to have the wrong time-constant (irregular drift of trace), replace 8.2-k resistors with 6.8 k 1/4 watt 10% resistors. General Electric and other tube brands should not be mixed in the distributed amplifier.

7.7 GAIN SET:

7.7.1 Maximum Gain: Install EP53A Gain Adj Adapter between plug-in and scope, or install TU-1 (or TU-2 set to 1:1) Test Load Unit. Apply 200 mv of calibrator signal to banana jack on EP53A or to TU-1 or TU-2 input. Turn Gain Adj control for main vertical amplifier (facing down on amplifier chassis) full clockwise. Log vertical deflection. If more than 2.2 cm (10% reserve gain) proceed with 7.7.2. If less than 2.2 cm but more than 2 cm, the scope may be usable for some purposes, but difficulty may be encountered in making proper risetime and bandwidth (Step 15). If less than 2 cm proceed with 7.7.3.1.

7.7.2 Set Gain: If maximum gain is adequate, reduce setting of Gain Adj control for exactly 2 cm deflection with 200 mv calibrator input. (If TU-2 is used, set toggle switch to "250:1" and apply 100 v from calibrator. Reduce setting of Gain Adj for exactly 4 cm deflection).

7.7.3 Troubleshooting:

7.7.3.1 Insufficient Gain: Check stage gains with a regular voltage-measurement plugin in the instrument under test, to assure even phase-splitting ahead of the main vertical amplifier input. Measure amplitude at each grid, comparing gain against the table below.

Amplifier Stage	Gain Min	Gain Normal
12BY7A or 6AW8 Input Amp (Gain Adj Clockwise)	4 - 4.5	5.5 - 6
6BQ7/6DJ8 CF Stage*	0.7	0.7
Distributed Amp (6CB6's or 6DK6's)	20 - 22	22 - 24

*Above S/N 9292, 0.7 gain is total for both CF stages.

If both input and output stages are at or near minimum gain, tubes in one or both stages may require replacement.

If overall amplifier gain is 70 or more, the trouble is probably not in the amplifier, and may be in CRT sensitivity. Recheck HV supplies (4.1) and Deflection Factor (6.4).

If VA tubes are changed, be sure to repeat all parts of Step 7. If tube-change does not provide correct gain, check plate load resistors, screen potentials, decoupling networks, filament lines, etc. Also check calibrator accuracy (Step 8), and input DC level (7.1.2).

7.7.3.2 Gain Setting Unstable: Check Gain Adj control for intermittency. Check for changes in input stage grid DC level. Check decoupling circuits, electrolytic capacitors and DC shift network components (7.4.3). Monitor for power supply fluctuations, and intermittent plate or cathode resistors. Try using Calibrator signal from test scope, in case intermittency is in calibrator. Check VA tubes for gas (but see note in 7.2.2.3).

9.2.3.4 Trigger Sensitivity -- continued: If a bright burst of sweeps occurs as the spot passes slowly over the triggering point, or if sweep is triggered on both upward and downward passes for either slope setting, Trigger Sensitivity setting is too high. Advance Stability control until sweep just free runs with no vertical input, then back off just slightly. Advance Trigger Sensitivity if necessary, until double-triggering or burst-triggering occurs, as described above. Now, back off Trigger Sensitivity until neither aberration occurs as spot is positioned past triggering point on either slope setting. Then back off 10-15° further.
Reapply 60 cycle waveform, reduce intensity (and reduce Time/Cm setting if desired) and touch up Trigger Level Centering as in 9.2.3.3.

9.2.3.5 Preset Stability: In instruments equipped with this feature, turn Stability control counterclockwise into "Preset" switch position, turn Trigger Slope to +Line and Main Sweep Time/Cm to 10 μsec/cm. With no vertical input, a dim trace will appear if circuit is already in adjustment. Locate Preset Stability control on sweep deck just behind front panel. Rotate this control throughout its range and note the settings for no trace (lockout), dim trace (triggerable) and bright trace (free-run). Set the control to the middle of the "triggerable" range.

9.2.3.6 Automatic: Set front-panel Stability control to "Triggerable" range (not necessary in later instruments with "preset" feature), turn Triggering Mode to Automatic (or "AC Auto"), Trigger Slope to +Int, and Time/Cm to 10 μsec/cm. A dim trace should appear, and should brighten very slightly when Trigger Slope is changed to +Line. Return to internal triggering and 1 msec/cm sweep, and apply 1 v of calibrator waveform to vertical input with vertical Volts/Cm at 10. A stable 1 mm display should result. See that stable triggering on the proper slope occurs in +Int -Int slope settings.

9.3 FINAL CHECKOUT: REMOVE JUMPER installed in 9.2.3.1, and increase Calibrator output to 2 v. Set Triggering Mode to AC Slow and adjust Triggering Level if necessary to obtain triggered display. At some Triggering Level setting near "0", it should be possible to switch back and forth from + to - slope and obtain stable triggering. Log the minimum size signal which can be displayed trigged on either slope without readjustment of the Triggering Level. Switch to AC Fast and repeat procedure. Switch to DC mode and reposition display as required for switchable triggering as above (minimum signal here will be larger than for AC slow because of the DC divider circuitry). Touch up circuits again if necessary, to meet the following specs:

Internal (Calibrator Wave-form):

AC Slow and AC Fast:	2 mm signal anywhere within graticule, switchable with Triggering Level at "0".
DC Mode:	2 mm signal within 2 mm of graticule center, switchable with Triggering Level at "0".

External (Calibrator Wave-form):

AC Slow, AC Fast:	200 mv signal, switchable with Triggering Level at 0.
DC Mode:	200 mv signal, switchable with Triggering Level slightly clockwise from 0.

11.1.4 Sweep Amplifier Check: With the Magnifier on and sweep positioned as in 11.1.3, rap sharply on the scope with your hand, watching for horizontal microphonics. Now, turn Magnifier off and on at about 5 second intervals, watching for slow drift after switching (DC Shift). Repeat with sweep positioned far to the left. If microphonics or DC shift appear, see 11.2.5. Check Cal Record if O.K.

11.1.5 Main Sweep Timing:

11.1.5.1 Calibration Check: Turn Horizontal Display switch to Main Sweep Normal and obtain a triggered display of 1 millisec markers. Check timing over middle 8 cm as in 11.1.1.1, and log any timing error at 9 cm mark in Cal Record.

11.1.5.2 Main Sweep Vernier (R99M) Adj: With display as in 11.1.5.1, locate R99M on the Main Sweep Time/Cm Multiplier bracket.

> CAUTION: The screwdriver slot in this control is at -150V. Use tool with insulated shaft for adjustment.

Adjust this control for exact Main Sweep timing over middle 8 cm of display. Note any adjustment in Cal Record.

11.1.6 Main Sweep Length: Remove vertical input and free-run Main Sweep at 1 msec/cm. Adjust Sweep Length control (on bracket above main sweep deck) for 10.5 cm sweep length. Log in Cal Record.

11.1.7 Sweep Amplifier Fast Sweep Check: Free-run Main Sweep again, with Horizontal Display Switch on Main Sweep Normal. Observe sweep length as Time/Cm is turned to 0.1 μsec/cm. If horizontal amplifier is functioning normally, sweep will lengthen appreciably to the right at the fastest sweep rates. If sweep remains at 10.5 cm length or shortens at fastest sweep rates, horizontal amplifier tubes may be too weak to permit calibration of fast sweeps or C240 and C254 are far out of adjustment. For either difficulty see 11.2.7.1.

11.1.8 Delaying Sweep Length: Turn Horizontal Display switch to Delaying Sweep and turn off Main Sweep. Free-run Delaying Sweep at 1 msec/cm. With Delaying Sweep Length control (concentric with D.S. Time/CM knob) clockwise, check for 10.2 to 10.8 cm sweep length. Log in Cal Record. Now turn Length control CCW, and check for 3.2 to 3.8 cm length. Log actual length in Cal Record.

11.1.9 Sweep Amplifier Gain: Turn Horizontal Display switch to Ext Sweep, turn Magnifier on, and turn Stability Or Ext Sweep Atten clockwise. With Atten toggle switch at X1, patch 1-volt Calibrator output to Ext Sweep In and check for two-dot display. Dots should be spaced at least 5 cm apart. Divide cm deflection into 1 and log in Cal Record (volts per cm).

11.2.6 Timing Problems:

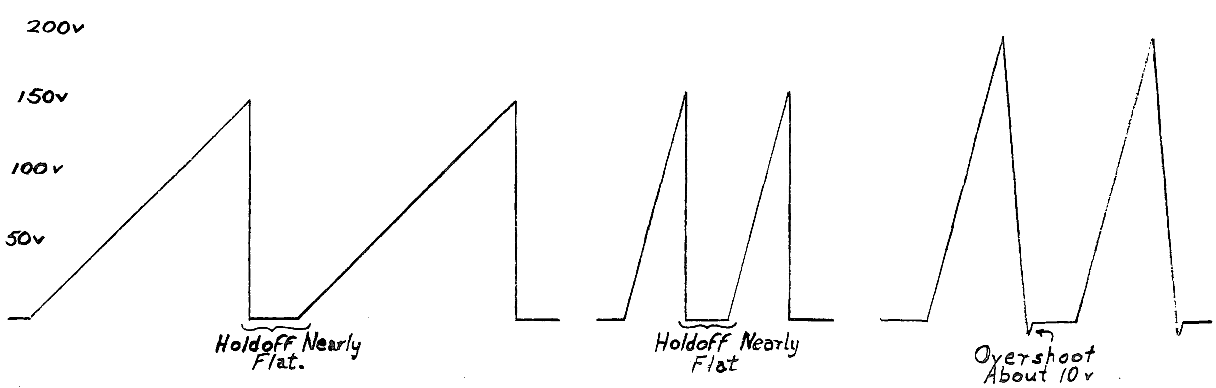
11.2.6.1 Delaying Sweep Won't Time: Try replacing V190, V180 and/or V150. Recheck -150 v supply for correct voltage. If Max Sweep Length (11.1.6) is off, recheck Horizontal Gain (11.1.9). Try setting up basic timing on 2 msec/cm (timing component check). If timing is not consistent, try replacing R190A, B, C, before changing timing capacitor.

11.2.6.2 Main Sweep Won't Time: If R99M has insufficient range to match Main Sweep to Delaying Sweep timing, the error may be in Delaying Sweep timing, used to set Sweep Cal. See if indicated Main Sweep timing error is substantially the same in all ranges from 500 msec/cm to 100 μsec/cm. If so, the error is probably in the Delaying Sweep (see 11.2.6.1 above). If not, try replacement of V90, V80 and/or V85 before changing Main Sweep timing resistors or capacitors.

NOTE: Frequently, timing problems that seemingly can be traced directly to specific timing resistors are actually due to leakage or gas in sweep generator tubes. Always try tube replacement first before changing timing components.

11.2.7 Sweep Shortens at Fast Rates: If a free-running sweep fails to lengthen at faster sweep rates, try replacing V265 and V272 (see TUBE REPLACEMENT NOTE, previous page). If tube replacement does not produce an increase in fast sweep lengths, C240 and C254 are probably far out of adjustment, and will have to be preset before fast sweep timing. Replace original tubes, and proceed with 11.2.7.1.

11.2.7.1 C240, C254 preset: Free run Main Sweep at 10 μsec/cm. Check probe compensation of test scope, and set test scope to 50 μsec/cm. Use test scope and probe to observe 150 v sawtooth waveform at R.H. deflection plate of scope under test (green/white coded lead from pin 8, V272 to deflection plate).
Adjust C240 and C254 (located at the rear of the sweep chassis) for optimum square corner at the start of the holdoff portion (See Fig 11-2.7A) of the sweep waveform. Final adjustment will be made in Step 11.4.2.



A. Scope under Test, 10 μsec/cm Test Scope, 50 μsec/cm Amplitude approx 155 v

B. Scope under test, 1 μsec/cm Test scope, 50 μsec/cm. Amplitude approx 160 v

C. Scope under test, 0.1 μsec/cm. Test Scope, 5 μsec/cm. Amplitude approx 190 v

Fig. 11-2.7 FAST SWEEP WAVEFORMS

TIME/CM Setting	MULTIPLIER Setting	VARI-ABLE	TIME MARKERS From 180A	CORRECT DISPLAY	COMPONENT (S) Being checked
100 μsec	X 1		100 μsec	1 mark/cm	C99C & D
100 μsec	X 2		100 μsec	2 marks/cm	R99E & F
100 μsec	X 5		500 μsec	1 mark/cm	R99D
100 μsec	2.5-1	CW	100 μsec	1 mark/cm	R99L
100 μsec	2.5-1	CCW	500 μsec	5 (min) in 10 cm	R99K, R99L
100 μsec	5 - 2	CCW	500 μsec	10 (min) in 10 cm	Switch
100 μsec	12 - 5	CCW	1 msec	12 (min) in 10 cm	Switch
Check for smooth <u>Variable</u> action in all ranges					R99L
10 msec	X 1		10 msec	1 mark/cm	C99B
100 msec	X 1		100 msec	1 mark/cm	C99A
1 sec	X 1		1 sec	1 mark/cm*	R99C
1 sec	X 2		1 sec	2 marks/cm*	R99B
1 sec	X 5		5 sec**	1 mark/cm*	R99A

*Position base-line down off-screen to avoid burning phosphor while making measurements at the 1, 2, 5 sec/cm sweep speeds.

**If Type 180 is used, use 1 sec markers and check for 5 marks/cm.

TABLE 11-1

11.3.2 <u>Troubleshooting</u>:

11.3.2.1 <u>One Calibrated Sweep Off</u>: Check value of component indicated in right-hand column.

11.3.2.2 <u>Error Increases on Slowest Sweeps:</u> Try replacing V90, then V80 (possible leakage or gas). Check for possible leakage across tube sockets, switch wiring, etc. 500 meg ohms leakage will throw 5 sec/cm timing off by over 10%. Slow sweep (1, 2, 5 sec/cm) timing can also be introduced by emission from cathode to shield of V80. If the V80 shield (pin 6) is grounded in your instrument, remove the ground connection, and connect pin 6 (shield) to pin 2 or 7 (plate).

11.3.2.3 <u>All Sweeps Checked Show Constant Error</u>: Recheck 11.1.4. If OK, measure R99F (can be measured on switch if V90, & V80 removed) and C99C.

11.3.2.4 <u>General:</u> Check for correct voltages and waveforms throughout timing circuits; try removing V73; check for malfunction of V85 or neon bulb B95. Recheck Horizontal Amplifier; try Step 11.5.1 for severe waveform aberrations with both sine and square-wave displays.

13.2.2 5 μsec/cm Range: (Continued)

Log 1cm and 9 cm dial readings for 10 μsec/cm and 2 μsec/cm sweeps. Difference between readings, as before, must be 8.00 ± 0.05, for each sweep rate.

13.2.3 Troubleshooting:

13.2.3.1 Excessive Timing Error: Examine Delaying Sweep display closely, and see if direct display error corresponds to error indicated by Helidial. If not, try replacing Delay Pickoff tubes, starting with V195, V196 and V228. If error is confirmed, try tube replacement in Delaying Sweep generator, starting with V190, V150, and V180. Timing components are probably OK, unless 50 μsec or 5 μsec/cm sweeps cannot be brought in with C190D and C190F respectively.

13.2.3.1.1 Excessive Display Error, 2 μsec/cm: If 2 μsec/cm timing is O.K. according to the Delay Time Multiplier and using the Main Sweep Delayed mode, but the Delaying Sweep display itself indicates excessive error (± 2 to 4%), C240 may have been mis-set (Step 11.4.2.1). Try setting C240 to correct the delaying sweep display error, then repeat step 11.4, but without readjusting C240 again, if possible. A compromise adjustment may be necessary to keep both sweeps within display tolerance.

13.2.3.2 Excessive Sweep-Start Delay: Sweep-start delay involves Delay Pickoff, Trigger-Gate and Main Sweep Gating Multivibrator circuits as well as Delaying Sweep Trigger and Sweep circuits. It is only partially compensated for in the Main Sweep Delayed mode by the vertical amplifier delay system. Try changing oldest tubes in these circuits first. If trigger-pickoff system in vertical amplifier is suspect, try triggering Delaying Sweep externally directly from 180 (A). Recalibrate sections affected by tube changes before proceeding. Failure of C197 (in V195 grid divider circuit) will cause both non-linearity of fast sweeps and excessive "sweep start delay". Failure of compensating capacitor in any multivibrator grid divider circuit will slow down action and add to delay.

13.3 LINEARITY CHECK: Check linearity at 50 μsec/cm and 5 μsec/cm as in 12.5.3. Maximum linearity error, 2 small divisions on Helidial (.02). Log maximum error, and point at which it occurs for each Sweep rate in Cal Record.

13.3.1 Troubleshooting: Linearity problems may be caused in either sweep generator or delay pickoff circuits. Try replacing V190, V150 or V180 in generator; V195, V196 or V228 in pickoff circuit first. Check C197 (to grid of V195) and C187 (to grid circuit, V150B) for possible open.

13.4 JITTER CHECK: Set up as for Pickoff Drift (Step 12.4.1), with Main Sweep Time/Cm 1000 times faster than Delaying Sweep. Adjust Delaying Sweep Stability and Triggering Level controls for minimum jitter of Main Sweep Delayed display. Jitter at 1.00 cm delay should not exceed 2 mm; at 9.00 cm, 4 mm. Log actual jitter if within spec. Otherwise, proceed with 13.4.1.

13.4.1 Troubleshooting: Try replacing Main Sweep and Delaying Sweep Holdoff tubes (V54, V150, V140); re-check for excessive power-supply ripple. Try replacement of Delay Pickoff tubes. Repeat calibration sections involving any tubes replaced. If tube replacement fails to correct jitter, check R195, R208 and R209 for excessive noise; try replacing V37, V43, V190, V180, V155, and/or Delaying Sweep trigger tubes.

15.6 TROUBLESHOOTING: Most common malfunctions and aberrations in the vertical amplifier circuitry will have been cleaned up by tube and component replacements in Steps 7 and 15.1. Listed below are some of the unusual and infrequent failures causing effects only noticeable during fast-rise observations.

15.6.1 Risetime Too Slow for Correction by Adjustment: Open suppressor bypass capacitor(s) in distributed amplifier. Open compensating capacitor across 47 or 33 ohm series resistor in cathode of driver stage. Increase in plate-load resistor in input amplifier stage. Change in input or DA stage cathode or screen resistors. Possibly open 0.68 pf "speedup" (series) capacitors in delay line.

15.6.2. Excessive Spiking, More than 30 mc "Bandwidth": Open Capacitor in plate line.

NOTE: Be sure that "spiking" is not overshoot due to cathode interface (See Step 7.1.3 and Fig 7-4). In instruments below S/N 9292, try removing slugs from L1041 and L1022: These may have been added in error.

15.6.3 Excessive "Termination Bump": Failure of the fixed or variable capacitors or heat damage to R L components in the termination network will cause uncorrectable wrinkle about 1/2 μsec from the leading edge. Replace any out-of tolerance or damaged components.

15.6.4 Oscillations, Severe Single-Frequency Ringing: Check for open bypass capacitor, particularly on filament line or at plate of CF. Failure of 150 pf inter-cathode coupling capacitors in DA may cause oscillations in the 100-200 mc range. Be sure that the (white) trigger pickoff lead is dressed away from signal circuits near the 16 pin interconnecting socket.

NOTE: Certain instruments in the serial range 10,000 to 13,000 tend to oscillate when used with some Type 53/54C and CA plug-ins, sometimes only at extreme positions of the vertical position control. Check the location of C1054, the .005 bypass disc capacitor from the DA common plate supply to ground. If this is located at pin 5 of V1054, remove it and install it between the load end of R1054 (167 Ω, 5 watt) and the ground lug on C1005 adjacent to this terminal. This should eliminate the oscillations. In some cases (S/N 9292-up) a .01 μf 600 v discap from the B+ end of L1064 to the ground lug on the adjacent 12BY7A socket eliminates the problem completely.

15.6.5 Miscellaneous Abberations Not Correctable by Adjustment: Possible failure of components in RC balancing networks in delay line.

15.6.6 Step Waveform Tilts Downward to the Left: If the first 1/2 μsec of the waveform tilts downward to the left, giving the appearance of serious "undershoot" at about 5 μsec/cm, it may be due to defective D.A. tubes. (Figure 7-5). Try a new set of tubes.

SECTION 5

PARTS LISTS

0 RECOMMENDED TUBE AND RECTIFIER SPARES FOR REPLACEMENT AND COMPARISON PURPOSES.

0.1 TEKTRONIX, INC. SELECTED AND AGED TUBES:

Serial No. Range 101-9291: 2 ea P/N 157-039 6AW8*
14 ea P/N 157-037 6CB6

Serial No. Range 9292-up: 2 ea P/N 157-053 12BY7A*

*Both tubes should carry same subgroup No.

0.2 STANDARD COMMERCIAL "RAW" TUBES (Brand preferences as noted):

Serial No. Range 9292-up: 14 ea Type 8136, Tektronix p/n 154-367. Use of commercial 6DK6 is not recommended.**

All Serial Ranges:
4 ea 6DJ8/ECC88 or 6922/E88CC***
4 ea 6AU6
4 ea 6U8A, if used as V20 etc, otherwise 2 ea.
2 ea 6080, 12B4, 5642.
1 ea 6AU5, 6AL5, 6CL6, 5651, 12AL5, 12AU6, 12AU7, 12AX7 and 12BY7A.

**Note on Type 6DK6 tubes: 6DK6's tend to develop "cathode interface" (see page 3-23) after several hundred hours' operation, causing overshoot in the scope display of step waveforms. Most commercial 6DK6's develop this defect to an objectionable extent quite rapidly, and their use is no longer recommended. The G-E Type 8136 is specially designed with a "passivated" cathode to minimize this type of deterioration, and is the only type now recommended for use in the Tektronix oscilloscopes formerly using 6DK6 tubes.

***These tubes are a direct replacement for Type 6BQ7A used in early instruments, at a considerable increase in reliability. If foreign-made tubes are unavailable to you, maintain 6BQ7A stocks as follows: 8 ea "raw" 6BQ7A (Sylvania) and 2 ea, Tektronix, Inc. selected and aged 6BQ7A, P/N 157-022 for use in horizontal output circuits (V265 & V272.)

Tube stocks maintained at indicated levels should be adequate for 1-6 instruments. Tube stocks should be considerably larger at the start of a recalibration program, however, as instruments neglected for a long period may require large-scale tube replacements.

0.3 CATHODE RAY TUBES: Projected lifetime of CRT's in normal use is 3-5 years. Shelf life, however, is only 1-2 years without periodic activation, so prolonged storage of spares is not recommended. See section 6.4.2.2.

0.4 SELENIUM RECTIFIERS: Further stocking of selenium rectifiers is not recommended: Full replacement with silicon types is suggested after first selenium failure in an instrument. Projected normal selenium lifetime in use is 2-4 years. Modification kit 040-239 replaces all selenium rectifiers with silicon diodes. The complete kit is priced about the same as a full set of seleniums.

Knobs

		Old Type 101 thru 1051 Except*	New Type 1052 & up Plus*
Knob, red, white dot, for 1/8" shaft Used: Trig.Mode; Length (Delaying Sweep); 5X Magnifier; Multiplier; Sq. Wave Calibrator.	(5)	366-017	366-038
Knob, red, white dot, for 3/16" shaft Used: Stability (Main Sweep); Vernier; Stability (Delaying Sweep).	(3)	366-018	366-039
Knob, black, flanged, coaxial type, 1/4" center hole Used: Trig. Slope; Time/CM (Main Sweep); Time/CM (Delaying Sweep); Multiplier; Sq. Wave Cal.	(5)	366-021	366-040
Knob, black, flanged Used: Horizontal Display.	(1)	366-020	366-042
Knob, black, white dot Used: Scale Illum; Astigmatism; Intensity; Focus	(4)	366-019 S/N 6151 & up	366-044 366-033
Knob, black, flanged, coaxial type, 17/64" center hole Used: Triggering Level (Del. Sweep); Triggering Level (Main Sweep); Horizontal Position.	(3)	366-022	366-046
Knob, red, Preset engraved Used: Stability (Main Sweep) Preset stability mod kits			366-064

For CM of Delay of Delay Time Multiplier see Dial, Miscellaneous.

*New knobs used on SN's 1025 thru 1028. The new knobs are basically the same as the old type except for a slight change in appearance; color is the same. All knobs will be replaced by the new type knob unless specifically requested by the customer to supply the old type.

Selenium Rectifiers *

SR732	5-250 ma plates per leg	106-012 *
SR740	5-500 ma plates per leg	106-013 *
SR756	4-500 ma plates per leg	106-019 *
SR780	4-250 ma plates per leg	106-014 *
SR790	5-125 ma plates per leg	106-015 *

Relays

K700	45-sec.	Thermal Time-delay	Amperite 6N045T	148-002
K701	Relay	4P2T	6 volt	148-004

*Replacement with silicon diode modification recommended. See page 5-0.

Switches

All changes made to Type 545 at SN 13,344 were made to RM45 at SN 306.

			not wired	wired
101 thru 13,343	SW1 & SW5	Trigger Slope & Mode	260-099	262-080
13,344 & up	SW1 & SW5	Trigger Slope & Mode	260-099	262-183
Added 7401 & up	SW43 concentric with R14 & R43		311-096	
	*SW55	Time/CM	260-010	262-063
	SW90	Multiplier	260-011	262-064
	SW100	Atten	260-014	---
	SW113	Slope	260-014	---
	SW190	Time/CM	260-009	262-060
	SW200	Horizontal	260-007	262-061
	SW235	Reset, Main Sweep	260-017	
	*SW254	5X Magnifier	260-010	262-063

*Note: SW254 and SW55 are concentric. Furnished as a unit.

			not wired	wired
101 thru 8266	*SW670	Volts, Millivolts, Off)	USE	262-132
101 thru 8266	*SW680	Square Wave Calibrator)	~~260-013~~	~~262-065~~
8267 & up	*SW670	Volts, Millivolts, Off)		
8267 & up	*SW680	Square Wave Calibrator)	260-177	262-132
	SW701	Power On		260-134

*Note: SW670 and SW680 Shafts are concentric. Furnished as a unit.

Thermal Cut-Out

TK701	Thermal Cut-out, Type SE11	128^{o}	260-070

Transformers

	T700	Plate and Heater Supply (Power)	120-037
Export, All SNs	T700	Plate & Heater Supply (Power)	120-086
	T801	CRT Supply	120-036

Vacuum Tubes

All changes made to Type 545 at SN 13,344 were made to RM45 at SN306.

101 - 13,343	V8	6BQ7A	Trigger Amplifier	~~154-028~~ USE	154-187
13,344 & up	V8	6DJ8	Trigger Amplifier		154-187
101 - 13,343	V20	6U8	Trigger Shaper		154-033
13,344 & up	V20	6DJ8	Trigger Shaper		154-187
	V37 A&B	6U8	Del. Trig. Ampl. & +Multi. Trig. Gate Gen.		154-033
	V43 A&B	6U8	-Multi. Trig. Gate Gen & Ready Ind.		154-033
101 - 13,343	V54	6BQ7A	Sw. Holdoff Cathode Follower	~~154-028~~ USE	154-187
13,344 & up	V54	6DJ8	Sw. Holdoff Cathode Follower		154-187
101 - 13,343	V58 A&B	6BQ7A	+Multivibrator & Multi. C.F.	~~154-028~~ USE	154-187
13,344 & up	V58 A&B	6DJ8	+Multivibrator & Multi. C.F.		154-187

TYPE 545

Vacuum Tubes Cont.

All changes made to Type 545 at SN 13,344 were made to RM45 at SN 306.

	V70	12BY7	-Multivibrator	154-047
101 - 13,343	V73 A&B	6BQ7A	Sweep-out C.F. & Gate-out C.F.	~~154-028~~ USE 154-187
13,344 & up	V73 A&B	6DJ8	Sweep-out C.F. & Gate-out C.F.	154-187
	V78	6AU6	Multi-trace Units Sync Amplifier	154-022
	V80	6AL5	Disconnect Diodes	154-016
101 - 13,343	V85	6BQ7A	Sweep-generator C.F.	~~154-028~~ USE 154-187
13,344 & up	V85	6DJ8	Sweep-generator C.F.	154-187
	V90	6CL6	Sweep Generator	154-031
	V113	12AU7	Trig. Ampl. C.F.	154-041
101 - 13,343	V120	6BQ7A	Trigger Amplifier	~~154-028~~ USE 154-187
13,344 & up	V120	6DJ8	Trigger Amplifier	154-187
	V130	6U8	Trig. Shaper Ext. Sw. C.F.	154-033
101 - 13,343	V140	6BQ7A	Comparator	~~154-028~~ USE 154-187
13,344 & up	V140	6DJ8	Comparator	154-187
101 - 13,343	V150 A&B	6BQ7A	Holdoff C.F. & Sweep-generator C.F.	~~154-028~~ USE 154-187
13,344 & up	V150 A&B	6DJ8	Holdoff C.F. & Sweep-generator C.F.	154-187
	V155 A&B	6U8	-Multivibrator & +Multivibrator	154-033
101 - 13,343	V172 A&B	6BQ7A	Gate-out C.F. & Multivibrator C.F.	~~154-028~~ USE 154-187
13,344 & up	V172 A&B	6DJ8	Gate-out C.F. & Multivibrator C.F.	154-187
	V180	12AL5	Disconnect Diodes	154-038
	V190	12AU6	Sweep Generator	154-040
101 - 6889	V195	6U8	Delay Pickoff	154-033
6890 & up	V195	6AU6	Delay Pickoff	154-022
Add 6890 & up	V196	6AU6	Delay Pickoff	154-022
	V216	6U8	Delay Trigger Shaper	154-033
	V228 A&B	6U8	Constant Current Tube & Delayed Trig. C.F.	154-033
101 - 13,343	V240 A&B	6BQ7A	Driver C.F. & Input C.F.	~~154-028~~ USE 154-187
13,344 & up	V240 A&B	6DJ8	Driver C.F. & Input C.F.	154-187
101 - 13,343	V246 A&B	6BQ7A	Calibrator C.F. & Horiz. Pos. C.F.	~~154-028~~ USE 154-187
13,344 & up	V246 A&B	12AU7	Calibrator C.F. & Horiz. Pos. C.F.	154-041
101 - 13,343	V265 A&B	6BQ7A	Sweep Amplifier & Sweep C.F.	~~157-022~~ USE 154-187
13,344 & up	V265 A&B	6DJ8	Sweep Amplifier & Sweep C.F.	154-187
101 - 13,343	V272 A&B	6BQ7A	+Sweep Amplifier & -Sweep Amplifier	~~157-022~~ USE 154-18
13,344 & up	V272 A&B	6DJ8	+Sweep Amplifier & -Sweep Amplifier	154-187
	V282	6CL6	Gated CF-current Booster	154-031
101 - 13,343	V670	6U8	Calibrator Multivibrator	154-033
13,344 & up	V670	6AU6	Calibrator Multivibrator	154-022
	V700	6AU6	-150 v DC Amplifier	154-022
	V710	5651	Voltage Reference	154-052
	V712	12AX7	-150 v Comparator	154-043
	V725	12B4	-150 v Series Regulator	154-044
	V726	12B4	-150 v Series Regulator	154-044
	V727	12B4	-150 v Series Regulator	154-044
	V742	6AU6	+100 v Comparator	154-022
	V748 A&B	6080*	+225 v & +100 v Series Regulators	154-056

Note: *May be a 6AS7GA, #154-116

(Revised 5-62)

TYPE 545

Vacuum Tubes (Cont.)

	V757	6AU6	+225 v DC Amplifier	154-022
	V765	12AX7	+225 v Comparator	154-043
	V782	6AU6	+350-v Comparator	154-022
	V784	*6080	+350-v Series Regulator	154-056
*Note: May be a 6AS7GA, #154-116.				
	V791	6AU6	+500-v Comparator	154-022
	V794	12B4	+500-v Series Regulator	154-044
	V803	6AU5	Oscillator	154-021
101 thru 9291	V810A,B	12AU7	DC Comparator & Shunt Regulator	154-041
	V820	5642	-1350-v Rectifier	154-051
	V821	5642	+8650-v Voltage Tripler	154-051

All changes made to Type 545 at SN 13,344 were made to RM45 at SN 306

	V822	5642	+8650-v Voltage Tripler	154-051
	V823	5642	+8650-v Voltage Tripler	154-051
	V824	5642	-1450-v Rectifier	154-051
101 thru 13,343	V840	6BQ7A	Unblanking Mixer ~~154-028~~ USE	154-187
13,344 & up	V840	6DJ8	Unblanking Mixer	154-187
Add 9292 & up	V1014	12BY7A	Input Amplifier	157-053
Add 9292 & up	V1024	12BY7A	Input Amplifier	157-053
101 thru 9291	V1025A,B	6AW8	Decoupling Amplifier & Amplifier	157-039
Add 9292-11,904	V1033	6BQ7A	Grid-line Driver ~~154-028~~ USE	154-187
11,905 & up	V1033	6DJ8	Grid-line Driver	154-187

All changes made to Type 545 at SN 11,905 were made to RM45 at SN 209.

101 thru 9291	V1040A,B	6AW8	Decoupling Amplifier & Amplifier	157-039
Add 9292-11,904	V1043	6BQ7A	Grid-line Driver ~~154-028~~ USE	154-187
11,905 & up	V1043	6DJ8	Grid-line Driver	154-187
101 thru 9291	*V1050A,B	6BQ7A	Driver C.F. & Int. Trigger C.F. USE	154-187
101 thru 9291	*V1052A,B	6BQ7A	Driver C.F. & Vert. Sig. Out C.F. USE	154-187
Add 9292 & up	V1054	6DK6	Trigger-Pickoff Amplifier	154-149
101 thru 9291	*V1060	6CB6	Balance Amplifier	157-037
Add 9292 & up	V1064	~~6DK6~~**	Trigger-Pickoff Amplifier	~~154-149~~
101 thru 9291	*V1066	6CB6	Internal Trigger Amplifier	157-037
101 thru 9291	*V1080-1132	6CB6	Output Amplifiers (12 tubes)	157-037
Add 9292 & up	V1084	12AU7	Indicator Amplifier	154-041
Add 9292 & up	V1104-V1214	~~6DK6~~**	Distributed Amplifiers (12 tubes)	~~154-149~~
Add 9292-11,904	V1223	6BQ7A	Vertical-signal Output C.F. ~~154-028~~ USE	154-187
11905 & up	V1223	6DJ8	Vertical-signal Output C.F.	154-187

Note: *Circuit numbers DELETED - SN 9292 and up.

**Use Type 8136 154-367

Type 545 Oscilloscope

CALIBRATION AND MAINTENANCE PROCEDURE

Additional copies may be ordered through Tektronix, Inc. field offices and overseas representatives. Specify Stock No. 070-282. Price $2.00, postpaid in the United States.

Edition B

March 15, 1961

TEKTRONIX
TYPE 545 OSCILLOSCOPE
CALIBRATION AND MAINTENANCE PROCEDURE

TABLE OF CONTENTS

ABBREVIATIONS

C.F. or cf	Cathode-Follower
CRT	Cathode-Ray Tube
CW	Clockwise
CCW	Counterclockwise
D.S. or Del'g Swp	Delaying Dweep
Ext	External
HV	High Voltage
Int	Internal
k	kilohm (10^3 ohms)
kc	kilocycle (10^3 cycles)
mc	megacycle (10^6 cycles)
mm	millimeter (10^{-3} meter)
M.S.	Main Sweep
msec	millisecond (10^{-3} sec)
mv	millivolt (10^{-3} volt)
M.V.	Multivibrator
nsec or mμsec	Nanosecond or millimicrosecond (10^{-9} second)
pf or μμf	Picofarad (10^{-12} farad)
p/n	Part Number
p-p	Peak-to-Peak
RMS	Root-mean-square
S/N	Serial Number
Spec	Specification
Trig	Trigger
v	volts
μf	microfarad (10^{-6} farad)
μμf	micro-microfarad (10^{-12} farad)
μsec	microsecond (10^{-6} second)
Ω	Ohms

SECTION I

USABILITY AND CONDITION CHECK

1 Make visual check for overheated components; make sure tubes are firmly in sockets; check to see that CRT pin connections are tight.

2 Install DC-coupled voltage-measurement plug-in preamplifier (Type 53-, 53/54-A, B, C, CA, D, G, H, K, L, M, or Z). Set plug-in controls as follows:

CONTROL	SETTING
MODE (If any)	A, A Only, DC
AC-DC	DC
POSITION	Mid-Range
VOLTS/CM	10
VARIABLE	Clockwise ("Calibrated")

3 Set front panel controls on oscilloscope itself as follows:

CONTROL	SETTING
Main Sweep TIME/CM	1.0 millisec/CM
MULTIPLIER	X 1
5X MAGNIFIER	Off
HORIZONTAL DISPLAY	Main Sweep Normal
TRIGGER SLOPE	+ Int
TRIGGERING MODE	AC Slow
Main Sweep STABILITY	Counterclockwise (Not "Preset")
TRIGGERING LEVEL	Counterclockwise
INTENSITY	Counterclockwise

4 Complete the following operational checks:

	Circuits and functions checked:
4.1 Apply power. Listen for click of time-delay relay after 20-45 seconds. Be alert for signs of serious malfunctions: Overheating, phosphor damage, arcing, etc.	Relays; Shorts; HV Supply.
4.2 Center the vertical deflection system after about two minutes, using the vertical beam position indicators as a guide. Spot or trace should not be visible.	Vertical Amp; Beam Indicators; HV Supply.
4.3 Turn Main Sweep STABILITY control full clockwise and slowly advance INTENSITY control. Trace should become visible in mid-range of control; further clockwise rotation should cause a uniform increase in intensity. (Do not advance too far; phosphor damage may result). Examine trace for even intensity at several sweep rates, 10 msec/cm to 10 µsec/cm at normal viewing intensity.	Sweep gen.; HV Supply; CRT Gas check. CRT Cathode.

	Circuits and functions checked:
4.4 Turn TIME/CM to <u>0.1 μsec/cm.</u> Sweep length should increase somewhat. Now, turn MAGNIFIER "On". With a slight advance of the INTENSITY control, the free-running sweep should be clearly visible without serious defocussing under average interior lighting conditions.	Sweep Amp. CRT Emission
4.5 Turn MAGNIFIER "Off". Focus the trace sharply and position to the top and bottom of the graticule. There should be no significant bowing of the trace. (Tilt of the trace is usually just a matter of physical rotation of the CRT.)	CRT Geometry
4.6 Apply 20 v of Calibrator signal to the vertical input, allowing sweep to continue free-running. Adjust plug-in GAIN ADJ. or VARIABLE as necessary for exactly 2.0 cm vertical deflection centered about the horizontal centerline. Position display to the top and bottom of the graticule. There should be no noticeable compression or expansion. (Spec: 1/2 mm)	Vertical Bal. L.V. Power Supply
4.7 Set calibrator for 50 mv output. With plug-in set for DC coupling (important), position trace to bottom graticule line. Now, turn red Calibrator knob to <u>Volts</u> and watch for trace drift. More than 1.0 mm drift in 15 sec indicates need for DC-shift adjustment.	D.C. Shift
4.8 Return to 20 volts Calibrator output and set Main Sweep TIME/CM to 1.0 msec/cm. Turn STABILITY* control slowly CCW until sweep just stops free-running; then rotate STABILITY control CCW <u>another</u> 10 degrees--this is the "triggerable" position of the STABILITY control. Turn TRIGGERING LEVEL control clockwise (or CCW) until you obtain a stable display of the Calibrator square-wave. Adjust FOCUS and ASTIGMATISM controls (they interact) for sharp lines--both horizontal and vertical. Check trace for vertical or horizontal jitter.	M.S. Trigger Sweep Generator Power Supply
*(Instruments with "Preset" feature only: Turn STABILITY control fully CCW into "Preset" switch position and check trace for a stable, triggered display.)	Preset
4.9 Set up Delaying Sweep for triggered operation (patch from <u>Vert Sig Out</u> to <u>Trig or Ext Swp In</u>, ATTEN switch to X1, etc.), turn Main Sweep STABILITY clockwise, Main Sweep TIME/CM to 20 μsec/cm, and Delaying Sweep TIME/CM to <u>5.0 msec</u>. Turn HORIZONTAL DISPLAY switch to <u>Delaying Sweep</u>, and patch from 6.3 VAC connector to vertical input. Adjust VOLTS/CM and VARIABLE controls for exactly 4.0 cm peak-to-peak vertical deflection, centered about the horizontal centerline. Set Delaying Sweep TRIGGERING LEVEL so that triggering point (start of sweep) is exactly at the horizontal centerline. Now, exactly 3 cycles of the 60-cycle waveform should be displayed across the 10 cm graticule.	Vert Sig Out 6.3 VAC D.S. Trigger D.S. Generator Sweep Cal

		Circuits and functions checked:
4.10	Turn Delaying Sweep TIME/CM to 2.0 msec, and DELAY TIME MULTIPLIER to 2.00. Adjust INTENSITY so a small brightened segment of the trace (about 2 cm from the start) is apparent. Use DELAY TIME MULTIPLIER to position this brightened spot along the first full cycle of the displayed sine-wave. As the brightened spot crosses the horizontal centerline of the graticule at the 360° point on the waveform, the DELAY TIME MULTIPLIER dial should read 8.33. Any significant deviation (more than 10 small divisions) indicates need of recalibration, and possible Delaying Sweep timing error.	Delay Pickoff Trigger Gate Gen. Delay Start/Stop D.S. Timing
4.11	Turn HORIZONTAL DISPLAY switch to <u>Main Sweep Delayed</u>. Set Main Sweep TIME/CM to 5.0 msec/cm. Check for exactly 3 cycles display across 10.0 cm (adjust "phase" of display with DELAY TIME MULTIPLIER).	M.S. Timing
4.12	Return HORIZONTAL DISPLAY switch to <u>Main Sweep Normal</u>; adjust STABILITY and TRIGGERING LEVEL controls for triggered display. Stable triggering should be obtainable in both +Int and -Int TRIGGER SLOPE positions as vertical deflection is reduced to less than 1.0 cm.	M.S. Trigger
4.13	Remove 60-cycle signal and apply Calibrator wave-form to plug-in. Check waveform and amplitude of Calibrator for each output from 100 mv to 100 v. Spiking or rounding of front corner may be due to the attenuator of the plug-in unit; any serious aberration in the bottom of the waveform is probably due to a Calibrator defect.	Calibrator Plug-in Atten.

5 If performance throughout the above set of checks has been satisfactory, the instrument-and-plug-in combination can be considered in generally good condition--satisfactory for most low-frequency (DC-500 kc) applications. For more exacting use, particularly involving fast-rise pulses or high frequencies, the full CALIBRATION AND MAINTENANCE procedure should be carried out.

SECTION 2

TEST EQUIPMENT REQUIREMENTS LIST

1 TEST OSCILLOSCOPE REQUIREMENTS.

1.1 GENERAL REQUIREMENTS: The test scope must be used for measurement of power-supply ripple, dual-trace switching characteristics, output waveforms, and for troubleshooting checks in the calibration procedure. The test scope should meet the following minimum specifications:

Triggered, calibrated, linear sweep, with 3% or better accuracy.

5msec/cm to 1 μsec/cm or greater sweep range.

5 mv/cm or better sensitivity at 100kc minimum bandpass, AC-coupled.

50 mv/cm or better sensitivity at 5 mc minimum bandpass, DC-coupled.

1.2 RECOMMENDED OSCILLOSCOPE TYPES:

Types	531 (531A)	541 (541A)	551
	532	543	555
	533	545 (545A)	
	535 (535A)		

Using the following Plug-In Preamplifiers:

(Preferred)	Type L
(Alternate)	Type B or H or Type C-A with Type D.
(Optional)	Type Z, for high-accuracy measurements.

1.3 OTHER USABLE INSTRUMENTS: (do not meet full specs in 1.1 above)

Types 310 (310A)
316
317
515A
516
524 (524AD)

1.4 OF LIMITED APPLICATION AS TEST INSTRUMENT:

Type 502, 503, 504, 560, 561, etc. Generally, only for power-supply and other low-frequency measurements.

2 PLUG-IN REQUIREMENTS FOR INSTRUMENT BEING CALIBRATED:

Type K (53/54K) or Type L (53/54L)
Type P
Type TU-1 or TU-2 dummy-load unit for standardizing power-supply measurements, checking microphonics, etc.
If Type TU-1 or TU-2 is unavailable, a Type C-A (or 53C or 53/54C) will be required.

3 SPECIAL TEST EQUIPMENT REQUIRED:

3.1 VOLT-OHM-MILLIAMMETER (Steps 2, 3, 4, 6, 7, 9, 10)

Accuracy: 2% or better, DC ranges
5% or better, AC ranges

With calibration chart for 1% accuracy at:

100, 150, 225, 350, 500 and 1200 or 1350v DC, and 105 and 125v 60 cycle AC (210 and 250v 60 cycle AC, if instruments wired for these voltages are to be calibrated).

3.2 AUTOTRANSFORMER, VARIABLE (Steps 2, 4, 7, and 15)

Range: 0-135v (0-270v for 230v instruments)
Capacity: 6.25 Amp continuous (3.2 Amp or more for 230v instruments)

3.3 FAST-RISE SQUARE-WAVE GENERATOR (Step 15)

Risetime: Less than 3 nsec (mμsec)
Output: Variable, 0.1 to 0.4v into 52Ω.
Rep Rate: Variable, 0.4 to 1.0 mc
Tektronix Type 107 or equal.

3.4 CONSTANT AMPLITUDE SINE-WAVE GENERATOR (Steps 9 and 15)

Frequency Range: 50 kc to 50 mc
Output Voltage: 0.4 to 10 v into 52Ω
Variation: 2% or less 50 kc to 30 mc
Tektronix Type 190A or equal

3.5 TIME-MARK GENERATOR (Steps 11, 12, 13)

Markers: 1 μsec to 5 sec in 1-5-10 steps each decade
Sine Waves: 5, 10, 50 mc
Accuracy: 0.1% or better (Type 180A: 0.03%), crystal-controlled
Tektronix Type 180A or equal

4 SPECIAL TEST EQUIPMENT DESIRABLE BUT NOT REQUIRED:

4.1 HIGH OUTPUT SQUARE-WAVE GENERATOR (Step 11*)

Risetime: Less than 20 nsec (mμsec) into 93 ohms
Output: 15v or more into 93Ω, continuously variable
100v or more into open circuit
Rep Rate: 25 cps to 1 mc
Tektronix Type 105 or equal

4.2 PRECISION DIFFERENTIAL VOLTMETER (Alternate to 3.1 above)

4.3 AC AMMETER

Range: 0-10 amp Fuse-protected
Accuracy: 5%

*Performance of this step is not usually critical for oscilloscope operation; the Type 105 is required, however, in calibration of plug-in preamplifiers.

5 ACCESSORIES REQUIRED:

* 1 - 52Ω cable (RG58A/U), 42" long, with UHF connectors. (Tektronix 012-001)
* 1 - 52Ω terminating resistor assembly, Type B52R, Tektronix p/n 011-001
1 - Tektronix Type EP53A Gain Adjustment Adapter, Tektronix p/n 013-005
1 - B52T10 52 Ω, 10-1 T-Pad. Tektronix p/n 011-006
** 1 - Test Lead, 18", equipped with banana plugs. (Tektronix p/n 012-031)
** 1 - Type P410, P510, or P6000, 10X Attenuator probe.
1 - Type P6001 X1 probe, (010-023) or modified P510 probe for X1 or X2 attenuation (Special probe required only when high sensitivity test scope is unavailable)
1 - "Resistive shorting bar" (See Note, Step 7).

*Supplied with Type 107.
**Supplied with Type 545.

6 ACCESSORIES DESIRABLE BUT NOT REQUIRED:

* 1 - 93Ω cable, 42" long, with UHF connectors. (Tektronix 012-003)
* 2 - 93Ω terminating resistor assembly, Type B93R, Tektronix p/n 011-011.
1 - Input Capacitance Standardizer, Type CS-47. Tektronix p/n 011-021.

*One supplied with Type 105.

7 TOOLS REQUIRED:

7.1 CALIBRATION TOOLS:

Insulated, low-capacitance screwdriver, 7" shank. (Jaco #125)
Hex alignment tool, 0.1". (Walsco #2543)
Recalibration Tool Assembly, Tektronix p/n 003-007.
Allen Wrench Set, .050" to 1/16".
"Spudger" -- non-metallic prod for lead dress, etc.
Screwdriver 1/4" bit.
(CRT Wrench 003-333 for CRT's not equipped with built-in handle.)

7.2 REPAIR TOOLS:

Soldering Iron, 30- to 75-watt, small chisel tip.
Needlenose pliers, smooth jaw.
Diagonal cutters, 4".
Screwdrivers, assorted Phillips and standard.
Nut Drivers, 3/16" to 1/2".
Dental Mirror, insulated handle.

8 GENERAL SUPPLIES:

Q-Tips, or similar cotton swabs.
Solder, low-melting point, 3% silver content, 20 gauge.
R-P Filter-coat spray for air filter.
Solvent, Non-toxic, for removing resin, etc (DuPont Freon-TF or equivalent).
Anti-Corona lacquer.
Canvas Squares, 6 X 6" for tinning and cleaning soldering iron.
Small, clean wiping rags.
Light machine oil for fan motor.

SECTION 3

CALIBRATION AND MAINTENANCE PROCEDURE

0 GENERAL INSTRUCTIONS

0.1 USING THE PROCEDURE: As far as possible, each step in this procedure is divided into three main parts: Measurement, Adjustment, and Troubleshooting. The calibrator needs only to proceed within the step far enough to secure specified performance, and may skip the remaining portions.

0.2 TROUBLESHOOTING: The troubleshooting procedure normally is arranged in order of probable causes: These should be checked out in the order given. In a few cases, involving high-value or hard-to-replace components, procedures are arranged as a process of elimination.

0.3 CAUTION: Steps are arranged to minimize interaction effects and the necessity for "backtracking". Any trouble-shooting should always start with a check of the power-supplies, and a complete recalibration should always follow the indicated order so that calibrations made first are not thrown off by later adjustments.

0.3.1 Example: Adjusting the low or high voltage power supplies after calibrating the sweep or vertical will require a complete recalibration of both sweep and vertical.

0.4 USING THE CALIBRATION RECORD AS A GUIDE: After the calibrator has become familiar with the attached procedure, the Calibration Record Section 4 can become his primary guide for a complete calibration, and only occasional reference need be made to the more detailed and involved test of the procedure.

0.5 ENTRIES IN THE CALIBRATION RECORD: Three types of entries are indicated for the Calibration Record (Section 4) ("Cal Record") in the procedure. "Note" generally indicates the calibrator should enter "good" "fair" "poor" "OK" "NG" or other appropriate comment in the space provided. "Check" usually calls for simply marking the record to indicate the performance of a step. "Log" calls for the recording of some specific figure (voltage, time, error, dial setting, etc.) in the appropriate space. In addition to the entries called for in the procedure, all parts replaced during calibration and troubleshooting, (perhaps with an indication of the defect), should be recorded in the right hand margin in the spaces provided. Generally they can be identified by their schematic symbol (e.g., V20, V58, R265, etc.).

1 PHYSICAL CHECKOUT.

1.1 DAMAGE CHECK: Remove cabinet, examine instrument for evidence of damaged or overheated components. Check to see that CRT pin connections are tight, and all tubes are securely in their sockets.

1.2 AIR FILTER: Check condition of air filter; note in Cal Record. If loaded with dust, wash in hot water and soap and dry, then coat lightly with RP "Filter Coat". Allow to dry thoroughly before reinstalling, as adhesive coating compound will otherwise be sprayed throughout the instrument when the fan is turned on. Note treatment on Cal Record.

> NOTE: Some instruments may be equipped with glass-wool filters rather than the E-Z Clean aluminum type. Glass-wool and paper filters are not washable. Replace when dirty.

1.3 FAN MOTOR: Check condition of fan motor and bearings. Fan blade should turn freely. Oil motor if necessary with light machine oil. CAUTION: Do not over-oil. Note on Cal Record.

1.4 CLEAN HV, CRT: Clean away any accumulation of dust or dirt in HV supply, F & I circuits (use Q-Tips), along HV leads, and on CRT. Do not remove CRT anode connector unnecessarily. On new-style instruments (with plastic anode-connector insert in CRT shield), CRT can be removed for cleaning or replacement without disturbing anode connector assembly.

1.5 GRATICULE, ETC.: Clean graticule and light filters if necessary. Graticule should be reinstalled with the scribed lines nearest to the CRT face. If a green filter is used, the graticule should be reinstalled with the clear slots at the top. If no filter is to be used, either the clear or the red slots may be "up". Always mount graticule so it can be positioned by the white plastic cam at the left to match usable vertical scan. The green filter should be installed outside the graticule for minimum parallax.

1.6 FUSE: Remove fuse and check for proper size. For 117 volt 60-cycle operation, 6 amp 3AG fast-blow; 3 amp for 234v operation. Log fuse size in Cal Record.

2 POWER SUPPLY.

2.1 RESISTANCE TO GROUND, LOW VOLTAGE SUPPLIES: Disconnect scope from power line; remove plug-in preamplifier.

2.1.1 Resistance Measurement: Locate power supply busses at rear of sweep chassis (supplies identified on chassis lip) or on the bottom of the power supply chassis, adjacent to the 10-Ohm metering resistors. Measure resistance to ground from each supply buss, and compare against table below. Log in Cal Record.

2-1 TABLE:

Supply	Resistance	
-150v	3000 ohms or more	Xfmr Primary - Infinite
+100v	5000 ohms or more	AC Power Leads - Infinite
+225v	5000 ohms or more	
+350v	10000 ohms or more	
+500v	25000 ohms or more	

2.1.2 Troubleshooting: Note DC supply wiring color codes. Black base indicates negative voltage, white base positive voltage. Stripes, starting with the widest, are 3-digit RMA color code (two figures and multiplier) indicating supply voltage. The coded wires permit tracing individual supplies throughout the instrument.

2.1.2.1 Dead Short: (DC supply): Look for blackened, swollen, or heat damaged components. If necessary, remove supply distribution leads one at a time to isolate trouble.

2.1.2.2 50-500 Ohms:(DC Supply): Look for possible dead short on load side of decoupling network, or for bad electrolytic capacitor.

2.1.2.3 1000-2000 Ohms: (DC Supply): Check electrolytics and for possible shorts on rectifier side of regulator circuits (shorted rectifier, capacitor, wiring, or transformer). Check for shorted tubes.

2.1.2.4 Resistance Reading: (Xfmr or Power Leads): Check Power On switch, power leads, fuse, and thermal cutout for possible hidden short or leakage. Remove primary leads from transformer if necessary, and check for internal leakage.

2.2 RELAYS: Install Dual-Trace Plug-In (or Type TU-2) and preset front-panel controls as follows:

Control	Setting
Intensity	CCW
Main Sweep Stability	CCW (but not into "preset")
Triggering Mode	"AC Slow"
Main Sweep Time/Cm	1 msec
Multiplier	"1"
Magnifier	"Off"
Delaying Sweep Stability	CCW
Plug-In Mode switch	"A Only"
Position control:	Midrange
Volts/Cm	"1"

Other controls "as is" or midrange.

Attach power cord from autotransformer to scope. Turn on scope and adjust autotransformer for 117v.

2.2.1 Delay: Check elapsed time before relay K701 closes (normal: 15-45 sec); log time delay in Cal Record.

2.2.2 Relay Action: Watch K701 for excessive arcing or sputtering during and after closure. Note apparent armature and contact condition in Cal Record.

If all indications are normal, check over scope for possible overloads or "danger signals" before proceeding with 2.3

2.2.3 Troubleshooting: Check out circuits in order given.

2.2.3.1 Time Delay Too Short: Defective K700 (6N045T); shorted R708 (12 ohms); shorted wiring; defective K701 (magnetic relay).

2.2.3.2 Time Delay Too Long: Defective K700, defective K701, open R708, broken leads. Check voltages at K700 socket; check K701 section 1 for poor contact.

2.2.3.3 Excessive Arcing, K701: Check for iron filings between armature and pole-piece (remove filings with scotch tape folded back on itself). Check for proper contact pressure. Clean, burnish, and reposition contacts if necessary. Check for excessive load currents (2.3.1.5).

2.2.3.4 Slow Pull-In, K701: (Chattering during closure) Defective K700. (6N045T) Try replacing.

2.3 LOW VOLTAGE REGULATED SUPPLIES:

2.3.1 Measurements:

CAUTION: Before making the measurements listed below, verify that your 117-volt 60-cycle AC power line is delivering a reasonably good sine-wave.

Regulated power supplies--as used in the Type 545 scope--depend for successful operation upon the 60-cycle input line voltage reaching a certain peak voltage each cycle.

An AC line voltage regulator should not be used if that regulator causes flattening of the peaks of the sine-wave.

Waveshape distortion does not usually produce a change in the voltage reading of an ordinary voltmeter.

To verify the waveform of the 60-cycle line, set the test scope to 5 msec/cm, and measure the output of the 6.3 VAC output connector on the scope under test. The waveform should have no excessive flattening of the peaks or other apparent distortion (a small--5%--step near the peaks is normal, caused by the oscilloscope rectifiers). With the Autotransformer set to provide 117v to the scope under test, the V-O-M should indicate approximately 6.3 VAC at the output connector, and the test scope should show 17.8v peak-to-peak. If, with a V-O-M indication of 6.3v, the peak-to-peak measurement is 17.0v or less, see 2.3.3.7 for methods of checking the actual peak-to-peak line voltage.

2.3.1.1 Voltages: Set AC line voltage to 117v and measure regulated DC supply voltages. All should fall within 2% of nominal values. Measure at test points at rear of sweep chassis or at the busses located alongside the 10-ohm metering resistors (mounted underneath the power supply chassis).

2.3.1.2 Ripple: If voltages are within tolerance, use test scope and probe to measure ripple. Ripple should be predominantly 120 cycles (6 cycles across 10 cm graticule at 5.0msec/cm). Be sure line voltage is at 117 v.

Compare against "Output Ripple" specs in table 2-2, page 3-6. If within tolerance, log output voltages and ripple in Cal Record.

2.3.1.3 Regulation: Reduce line voltage slowly and log in Cal Record the line voltage at which each supply drops out of regulation (sudden large increase in ripple amplitude). No supply should drop out above 105 line voltage. Check ripple at 125 line volts (some increase is tolerable). See that each supply output voltage remains within tolerance as line voltage is varied between 105 and 125 volts (295-350v P-P).

2.3.1.4 Input to Regulators: Return line voltage to 117 and log DC voltages at input to regulator circuits (pin 9 of 12B4's, pins 2 & 5 of 6080's).

2.3.1.5 Current: Measure voltage drop across 10-ohm metering resistors, convert to current (divide by 10 or 5) and log. The +225 and +350 supplies will vary as shown depending on sweep and position control settings.

	-150v	+100v	+225v	+350v	+500v	Trouble-shooting
Max. Output Ripple (p-p)	5 mv	5 mv	3 mv	6 mv	7 mv	2.3.3.2
Output Ripple (Typical)	3 mv	5 mv	1 mv	6 mv	6 mv	
Dropout (RMS Line Volts)	100 v	100 v	102 v	104 v	102 v	2.3.3.3
DC Input Voltage (@ 117 v)	+95 v	175 v	330 v	475 v	600 v	2.3.3.3
Min DC Input Voltage (@105 v)	+60 v	+140 v	+270 v	+400 v	+570 v	2.3.3.3
Current (Typical, ±10%)	200 ma	80 ma	115-130	250-340	65-70 ma	2.3.3.5
*Input Ripple (Typical)	10 v	7 v	10 v	16 v	8 v	2.3.3.2
*Xfmr Winding (RMS)	205 v	150 v	130 v	120 v	210 v	2.3.3.4

*Not normally measured. Included for troubleshooting reference.

TABLE 2-2: REGULATED LOW-VOLTAGE SUPPLIES--Specifications and Typical Values

All figures shown are "Typical" readings, except Output Ripple.
All measurements at 117 line volts except as indicated.

2.3.2 Adjustments:

2.3.2.1 -150 Adj: If -150 v supply does not fall within tolerance, locate internal "-150 Adj" control, on a bracket at the rear of the power supply chassis. Adjust this control to bring -150 v supply within tolerance. Note on Cal Record if this adjustment is made, and enter new voltage readings for each supply.

WARNING: Any change in the -150 v supply output voltage will change both vertical and sweep calibration, and will affect the accuracy of the square-wave calibrator. Do not make this adjustment unless full calibration check is to follow.

NOTE: The -150 v supply is the basic voltage stndard for all regulated supplies. It may be adjusted slightly within its tolerance (± 3 v) to bring "in" another supply that is only slightly out of voltage tolerance, if all other supplies still come within voltage and regulation limits.

There are no other power-supply adjustments. Follow troubleshooting procedure (2.3.3) if other supplies are out of tolerance, or if -150 v supply is not in tolerance near mid range of -150 v Adj control.

SUPPLY:	AFFECTS:
-150 v	1. All other supply voltages. 2. Sweep generator accuracy.
+100 v	1. All high voltage supplies (hence CRT sensitivity, and overall calibration). 2. Calibrator output voltage.
+225 v	1. Delay pickoff accuracy.
+350 v	1. Vertical amplifier linearity.
+500 v	1. Horizontal amplifier linearity.

TABLE 2-3: MAJOR DIRECT EFFECTS OF POWER SUPPLY OUTPUT VOLTAGE CHANGES

2.3.3 Troubleshooting: Remember that each positive regulated supply depends on the supplies "below" it for reference voltages and/or current. See schematic diagram for "stacking" of supplies. Always start troubleshooting with the -150 v supply and work upward. The +100 v supply depends for more than half of its total load current on the proper operation of the +350 supply and the vertical amplifier (distributed amplfier cathodes return to +100 v supply), and may be affected by defects in either circuit.

Before undertaking major repairs, recheck the accuracy of your line-voltage measurements. (Few VOM's have better than 5% inherent accuracy on AC ranges.)

2.3.3.1 Supply Voltage Out of Tolerance: Probable causes are listed below. Check in order indicated.

Output Voltage Low:

(a) Input voltage low. See 2.3.3.3
(b) Series tube (12B4 or 6080) weak. Replace.
(c) Speedup capacitor (.01 uf to grid of 6AW6 or 12AX7) leaky. Try replacing capacitor. Very slight leakage will cause large voltage error.
(d) Overloaded supply. See 2.3.3.5
(e) Shunt resistor failure (R724, 725, 748 etc.)
(f) Defective error-amplifier (6AU6) or comparator (12AX7). Try replacement.
(g) Precision divider out of tolerance.
(h) (100 supply only) Vertical amplifier cut off (350 v supply current subnormal) *

Output Voltage High:

(a) Error amplifier (6AU6) failure.
(b) Comparator (12AX7) defective.
(c) Insufficient load. Check for inoperative circuits.
(d) (+100 v supply only) Open filament in Delaying Sweep or Plug-In DC string.
(e) (+100 v supply only) Excessive current in distributed amplifier (+350 v will show overload).
(f) Precision divider out of tolerance.

*If fuse modification kit 040-227 for protection of the vertical amplifier has been installed, check condition of vertical amplifier fuse, located adjacent to the 10-ohm power supply metering resistors. If this fuse is open, check vertical circuits carefully for shorts before replacement.

2.3.3.2 Ripple Problems:

NOTE: Several millivolts of the calibrator waveform normally show on the +100 v supply while the calibrator is operating. Turn calibrator off while measuring ripple. Sweep circuit waveforms will also show up on all supplies if either sweep is operating. Unless sweep waveforms exceed 10 mv in amplitude (p-p) they may be ignored, and sweeps turned off for ripple measurement.

Ripple measurements made at the ceramic strip at the rear of the sweep chassis may show considerable 70 kc interference from the HV oscillator. This 70 kc pickup is mostly due to capacitive probe pickup and may be ignored unless it also appears at other points throughout the instrument. HV oscillator V803 (6AU5) may be removed during ripple measurements--or other test points used (as desired).

Ripple specifications are always peak-to-peak, and refer only to 60- and 120-cycle components. Random noise should not exceed a very few millivolts.

Excessive Output Ripple (10-50mv)

(a) Error amplifier (6AU6) or comparator (12AX7) weak. Try replacement.
(b) Series tube (12B4 or 6080) weak.
(c) Overloaded supply. See 2.3.3.5
(d) Excessive input ripple. (see below)
(e) Speedup capacitor (to 6AU6 or 12AX7 grid) open. Measure or replace.

Excessive Output Ripple (60 mv - 10 v)

(a) Low DC Input Voltage. See 2.3.3.3
(b) Series Tube (12B4 or 6080) dead.
(c) Error amplifier or comparator failure.
(d) Electrolytic capacitor failure. Disconnect and measure.
(e) Overloaded supply. See 2.3.3.5
(f) Poor power-line waveform. See 2.3.3.7

Excessive Input Ripple

(a) Overloaded supply See 2.3.3.5
(b) Input electrolytic capacitor failure. Disconnect and measure.
(c) Rectifier failure. Check DC to regulator. See 2.3.3.3

60-Cycle Ripple

(a) Rectifier failure. Check input ripple and DC to regulator. See 2.3.3.3
(b) Heater-grid or heater-cathode leakage in regulator tubes (check against input ripple).
(c) Heater-grid leakage in vertical or sweep circuits (Check for major display aberrations).
(d) Poor ground connection at comparator (12AX7) grid.

NOTE: Be sure 60-cycle ripple readings are not caused by ground-loop problems between test scope and scope under test.

2.3.3.3 Low Input Voltage to Regulator (Dropout above 105 v):

(a) Electrolytic Capacitor deterioration. Disconnect and measure.
(b) Bad relay contact. Check for voltage drop across contacts.
(c) Metering resistors damaged. Measure.
(d) Low voltage from transformer. See 2.3.3.4
(e) Supply overloaded. See 2.3.3.5
(f) Poor power line waveform. See 2.3.3.7
(g) Rectifier deterioration. This is probably if (selenium type) rectifier is over two years old. Replace with silicon rectifier modification kit. See Section 5, Recommended Tube & Rectifier stocks.

2.3.3.4 Low Voltage from Transformer:

NOTE: (Be sure to double-check meter calibration).

(a) Defective AC circuits. Check for voltage drop between each side of line and corresponding transformer primary terminal. Check switch, fuse and thermal cutout for intermittency.
(b) Defective transformer. Check for proper proportions between secondary winding voltages.

NOTE: Tektronix, Inc. transformers carry an indefinite warranty, and will be replaced at no charge, if a failure is not due to deliberate overload or to use of oversize fuses. However, make sure that transformer is at fault before ordering warranty replacement, as transformer replacement will be billed (invoiced) at current net price unless original transformer is actually defective. Defective transformer must be returned to Tektronix, Inc., for credit.

2.3.3.5 Supply Overload Indications:

(a) Metering resistors damaged. Measure.
(b) Actual overlaod. Recheck resistance to ground (2.1.1). Isolate overload by using decoupling and plate resistor drops to compute currents. Insert metering resistors in distribution busses if necessary. For severe overloads, see 2.3.3.6.

2.3.3.6 Severe Overloads, Fuse-Blowing, etc.:

(a) Operate scope at 1/2 to 1/3 normal line voltage (close K701 manually) to avoid component damage. Use a fuse-protected AC ammeter in place of the fuse, and bring up line voltage slowly from zero, while metering suspected circuits. If necessary, remove transformer secondary connections one by one until trouble is isolated.
(b) Fuse-blowing can be caused by an intermittent power-line connection, where the interruptions are not long enough to allow K701 to drop out. Do not install "slow-blow" fuses except for 50-cycle operation; this momentary- overload protection is needed.

2.3.3.7 Checking Power Line for Proper P-P Voltage: Two methods may be used to check the peak-to-peak value of the power-line voltage. One method requires a test scope equipped with a differential input capable of 100-1 common-mode rejection or better (i.e., 1% differential accuracy or better); the second requires construction of a silicon rectifier adapter for a 20,000 Ω/v V-O-M.

2.3.3.7.1 Differential Oscilloscope Method:

CAUTION: Do not attempt to make peak-to-peak voltage measurements on the power line using a "single ended" input oscilloscope. Differential voltages existing between the oscilloscope chassis ground, the "cold" side of the line, and the "earth ground" of the wiring conduit may present a serious shock hazard, large measurement errors, and/or equipment damage. If a differential plug-in (Type D, Type G or Type Z) or oscilloscope is not available, use the the meter method outlined in 2.3.3.7.2 below.

Set line voltage to scope under test to 117. After checking differential balance and calibration of test scope at 100 v/cm (with Type G, a pair of balanced probes will be necessary), measure the peak-to-peak voltage differential between terminals 1 and 4 on the power transformer of the scope under test. The p-p reading should be 330 v, ±10 v. If it is not, and correction of the power-line waveform is not possible immediately, perform step 2.3.1.3 using p-p rather than "RMS" voltage readings. For 105 v RMS, use 295 v p-p; for 117 v use 330 v p-p; for 125 v use 350 v p-p.

2.3.3.7.2 Rectifier Adapter Method: Construct a peak-to-peak adapter for your V-O-M, following the circuit in Fig 2-1. Use paper, mylar or oil capacitors; do NOT use electrolytic types. For accurate measurement, it is necessary that both diode and capacitor leakage be kept in the megohm range. Use the V-O-M to measure between the + and - terminals. After checking the performance of the adapter with known p-p voltages, proceed as in 2.3.3.7.1 above.

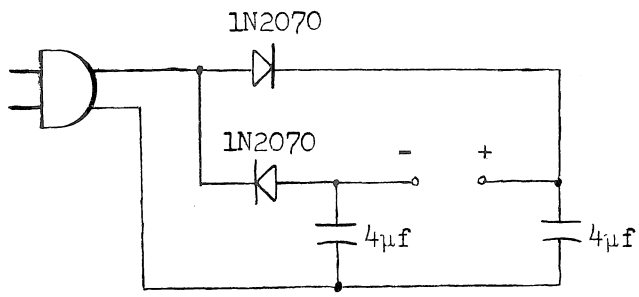


Fig. 2-1. Rectifier Adapter for V-O-M. Silicon rectifiers provide accurate peak-to-peak measurement capability. Capacitors should be 4-10 µf oil, paper or Mylar types, not electrolytic.

2.4.1 Measurements: Measure the DC potential at each of the elevated filament lines. Most convenient measurement point is at the transformer. Log measurements in Cal Record.

Transformer terminals	22/23	27/28	9/16	24/25
Elevated to (v dc)	+100	+225	+350	-1350

2.4.2 Troubleshooting:

2.4.2.1 No DC "Elevation":

(a) Bypass capacitor shorted.
(b) Series resistor to DC supply open.
(c) Filament or line shorted to ground.

2.4.2.2 Wrong Voltage:

(a) Heater-cathode short or leakage in tube on affected line.
(b) Leaky bypass capacitor.
(c) Leakage in transformer.
(d) (Terminals 24/25 only) Check HV supply (Step 4) for proper operation.

3 CALIBRATOR.

3.1 MEASUREMENTS:

3.1.1 DC. Reference: Turn Calibrator "Off". With precision DC meter, measure voltage to ground from "Cal Test Point"*. This should be 100 v ±1%. Log voltage if within tolerance.

3.1.2 Symmetry: Turn Calibrator to "Volts" or "Millivolts" range. Test-point reading on DC meter should be 45-55 volts (45-55% duty cycle & symmetry). If within range, log in Cal Record.

3.2 ADJUSTMENT:

NOTE: Setting the calibrator reference level determines the voltage-measurement accuracy of the entire instrument. Any error introduced in this step will be reflected in all voltage measurements made with the oscilloscope. Use precision DC differential voltmeter if available.

3.2.1 Cal Adj: If the 100 v calibrator reference level is out of tolerance (3.1.1) find the Cal Adj. control, located near the Calibrator switch, just behind the front panel. Adjust to exactly 100 v reading at test point. Note adjustment in Cal Record.

3.3 TROUBLESHOOTING:

3.3.1 Symmetry out of Tolerance: Probably deterioration of multivibrator tube, V670, usually a 6U8A. In some later instruments, half of V246 as well as V670 (6AU6) is in the multivibrator circuit. If tube replacement does not work, check timing capacitors and resistors in V670 circuit; check for leakage across tube sockets.

3.3.2 Cal Adj will not Correct 100 v Level: Recheck 100 v power supply. Try changing V246 or V670. R676 or R680 may have changed value. Check R681 and multivibrator components. See if Cal Output is shorted or overloaded (Resistance of Cal Test Point to ground, scope turned off, should be 20k ±1%). Also check 3.3.3 below.

3.3.3 Erratic Reading or Erratic Cal Output: Check Cal Adj pot for intermittency. Recheck +100 v supply. Replace V246, V670. Check for partially shorted output. See that switch is tightly mounted.

*Locating the Cal Test Point: In early instruments, no jack was provided. Measure from the top of R693 (9.5k precision) to ground, or from the cathode of V246 (usually pin 3). In later instruments, a pin-jack is provided on the lip of the chassis, adjacent to the calibrator circuit.

4 HIGH VOLTAGE SUPPLIES.

4.1 MEASUREMENTS:

4.1.1 HV Test Point: (Cathode Supply): Locate HV test point on F & I chassis above CRT shield on left-hand side. Measure between this point and ground (-1350 v ±3%).* Log in Cal Record if within tolerance. If not, complete step 4.2.1 before continuing.

4.1.2 Cathode Supply Regulation: Turn Focus control fully CW, Horizontal Display Switch to Main Sweep Normal, and Main Sweep Time/Cm to 1 msec. Advance Intensity control to about midrange. A bright, defocussed trace should appear. (If not, check 4.1.3 and troubleshooting procedures below. If spot appears, but no sweep, trouble is in sweep circuits.) Position the trace offscreen with the vertical position control.
Reduce line voltage to 105 v and turn Intensity control full clockwise. Log voltage at H.V. test point. Now, turn Intensity control full CCW and increase line voltage to 125 v. Log voltage at H.V. test point. Difference between these readings should not exceed 10 v. Excessive variation (poor regulation) will probably be due to defective V803 (oscillator), V810 (regulator) or associated components, possibly to weak V820 (rectifier).

4.1.3 Grid Supply: Turn Intensity CCW and measure grid supply voltage, which now appears at wiper of Intensity pot (center terminal). With F & I shield removed, grid voltage can also be measure at the junction of R830 (47k) and C832 (.015). Voltage should be -1450 v, approximately. Log.

4.1.4 +8650 Regulation (Blooming): Obtain a stable, triggered display of 2 cm of calibrator signal at 1 msec/cm. Run Intensity control throughout its range, and watch for any change in the size of the display (not counting thickening of the trace). If this "blooming" occurs, see 4.3.5.

4.2 ADJUSTMENT:

4.2.1 HV Adj: If -1350 supply is out of tolerance, locate HV Adj control, on underside of sweep chassis, just above power transformer. Adjust for -1350 v at HV Test Point. Repeat 4.1.

> CAUTION: Adjustment of HV Adj will change vertical and horizontal sensitivity of CRT and hence calibration of entire scope. Resetting of this control must be followed by complete recalibration.

*If V-O-M has 1200 v scale, measure between H.V. testpoint and -150 v bus, to give full-scale reading accuracy. Reading should be -1200 v ±40 v.

4.3 TROUBLESHOOTING:

4.3.1 No High Voltage: Check for oscillator operation by holding test scope probe near HV transformer. Before replacing oscillator or regulator tubes, check for low resistance or short in CRT cathode circuit. Try new V803, then V810. Check for open filaments in HV rectifiers. Try replacing V820 (See TUBE REPLACEMENT NOTE below).

4.3.2 HV ADJ Range Insufficient: Recheck +100 v supply (reference voltage for HV supplies). Try new V803, then V810. Check for leakage in C820, C855, or C857, or in power transformer (Terms. 24/25) to ground. Try new V820*. Check values of divider R812-815.

4.3.3 Intensity Range Too High: If the Intensity control will not extinguish a free-running sweep, recheck grid-supply voltage. If less than -1450 v to ground (sweep not running) replace V824*. If quiescent voltage is normal (and HV within tolerance), check for excessive gate amplitude. (Step 17.2). Possible leakage in CRT. Try replacement.

4.3.4 Intensity Range Too Low: If the Intensity control will not produce a visible spot at midrange (no sweep, beam centered), check grid-supply voltage. If more than -1450 volts, measure voltage at "low" side of supply (junction of C834 (.015) and 100 k resistor R834, or cathodes (pins 8 & 3 of V840). This should be +50 v with no sweep running. If this voltage is normal and grid supply is high, check for leakage or overload of cathode supply circuit. Replace V820*. If maximum intensity is inadequate, make sure that intensity-limiting modification (maximum intensity control, limiting electrical range of front-panel Intensity control) has not been installed. Also check CRT condition (Step 6.2).

4.3.5 Display Blooming with change of Intensity: Recheck regulation at HV test point. If variation is not over 10 v over the full range of the intensity control (sweep running), the cause may be excessive (several megohms) series impedance in the +8650 v supply. Check for possible poor connection at CRT anode, or in voltage tripler rectifier circuits. Try replacing tripler rectifiers V821, V822, and V823.

4.3.6 Bright Trace or Spot Immediately After Relay Closes: If a bright trace or spot appears immediately after time delay relay K701 closes, even when Intensity is CCW, V824 has too-slow warmup. Replace.

4.3.7 Persistent Troubles: If HV supply aberrations are not due to faults noted in 4.3.1-4.3.6, the HV transformer may be defective, and should be replaced. Like the power transformer, this unit carries an indefinite warranty, and a replacement may be obtained at no charge if the defective transformer is turned in. Get in touch with your nearest Tektronix Field Office or Overseas Representative.

*TUBE REPLACEMENT NOTE: Always check for leakage or overload if Type 5642 tubes require replacement. Under normal conditions, these tubes do not require frequent replacement. (If HV filter capacitors show signs of overheating, they should probably be replaced "on principle".)

Although only one of the tubes may actually be defective, both V820 and V824 must usually be replaced at the same time, to maintain proper voltage ratios.

5 MISCELLANEOUS FUNCTIONS.

5.1 BEAM POSITION INDICATORS:

5.1.1 Operation Check: Make sure sweep generators are not running. Bring up Intensity until spot is just visible on screen (refocus if necessary). Turn Magnifier on, and use position controls to position spot offscreen to the right, left, top, and bottom. See that the appropriate indicator lights are turned on (glowing) as the spot leaves the graticule area. Note proper performance of of indicators in Cal Record.

5.1.2 Troubleshooting: Horizontal indicators are driven directly by the horizontal output stages through resistive dividers. Check divider resistors for tolerance; check for proper deflection-plate potential (approx 310 v to ground) with spot centered.

Vertical indicators in instruments s/n 101-9291 are driven by the triode sections of the 6AW8 input amplifiers. Tube replacement will require vertical amplifier recalibration (Steps 7 and 15). Also check plate loads, etc.

Vertical indicators in later instruments are driven by an independent dual triode, V1084. Tube replacement is usually sufficient. If not, check R1083 and R1087. If these are 330 K, change to 390 K resistors.

5.2 HORIZONTAL POSITION CONTROLS:

5.2.1 Operation: Check for smooth, noise-free operation of Horizontal Position and Vernier controls. With Magnifier on, range of Vernier control should be about 10 cm. Note proper operation in Cal Record.

5.2.2 Troubleshooting: Except in later instruments, these controls operate through cathode-follower V246. If this tube is replaced, repeat Step 3.

5.3 ALTERNATE SWEEP SYNC:

Install Dual-Trace plug-in* set for "Alternate" mode, and free-run Main Sweep. Position the two (unmodulated) traces 2 cm apart. Observe waveform at Vert Sig Out on test scope. Run test scope at slower sweep rate than scope under test, and check for uniform switching of Dual Trace unit at all main sweep rates. The plug-in should switch channels at the end of every Main sweep. Note proper performance in Cal Record.

5.3.2 Troubleshooting: Erratic switching, or failure to switch: Check value of R78, located on sweep deck adjacent to LR 72. If 47 k, change to 36 k 5%. Try replacing V78. Try using a different plug-in. Check Main Sweep holdoff times (Step 14). Check LR 72, and V70.

*Or Type TU-2, set for "Dual Trace".

6 CRT F & I CIRCUITS.

6.1 CRT ALIGNMENT:

6.1.1 Check: Free-run Main Sweep and position unmodulated trace to center graticule line. Check for tilt of trace. See that CRT is positioned up tight against graticule, for minimum parallax. Note on Cal Record.

6.1.2 Adjustment: If necessary, loosen clamp around CRT base and rotate CRT for perfect trace alignment, using nylon handle on CRT socket. Push CRT up tight against graticule and retighten clamp. Recheck for perfect alignment, and repeat if necessary. (If no CRT handle, use CRT Wrench, Tek 003-333.)

6.1.3 Trouble Note: In instruments using the new brush-type anode connector (and plastic CRT shield insert) severe sweep and vertical aberrations sometimes result when CRT is repositioned, due to corona discharge or arcing from one or more displaced bristles of the brush. This can usually be cured by a slight rotation of the plastic anode-connector boot. If necessary, remove CRT, remove connector, straighten bristles, replace connector, and replace CRT (in that order, to avoid again deforming brush).

6.1.4 Miscellaneous Corona and Arcing Problems: Crackling or buzzing audible near the front panel of the scope indicates HV corona and/or intermittent arcing near the anode connector. If the trouble does not appear to be due to "wild" bristles in the connector itself, remove the CRT, and clean the area around the anode connector thoroughly; clean away all accumulated dust and dirt from the connector and from adjacent parts of the CRT shield. Corona inside the HV supply (at the rear of the sweep chassis) is usually traceable to poor soldering, dirt, and/or loss of anti-corona lacquer from the +HV terminals. All solder joints should be smooth and free of points or projections, and the ceramic terminals carrying +HV should be painted with anti-corona lacquer. Filament leads to V821, V822 and V823 all carry voltages between 2900 and 8700 volts, and should be carefully checked in case of corona problems.

6.2 CRT CONDITION:

6.2.1 Checkout:

6.2.1.1 Gas: At several sweep rates, check for smooth increase in free-running trace intensity as Intensity control is advanced slowly. Two peaks of intensity probably indicate gas in CRT.

6.2.1.2 Cathode Damage (Interface): At slow sweep rates (10 msec/cm to 100 µsec/cm) compare start of trace (at left) with the rest of the trace. Excessive thickening or brightness at the left may indicate "cathode interface".

6.2.1.3 Spurious Emission: Use viewing hood or darkened room to check for "doughnut" or other spurious pattern on screen with sweep generators off. Any display unaffected by Intensity control is due to emission from some point other than the cathode.

6.2.1.4 Normal Beam Current: At 1 msec/cm, obtain triggered display of 2 cm Calibrator waveform. Increase sweep speed to 1 µsec/cm. Advance Intensity control. Trace should become visible in normally lighted room (not facing daylight) before Intensity control reaches 3/4 rotation.

6.2.1.5 Phosphor: Check CRT for brown or void spots or streaks (burns due to careless operation). Note on Cal Record with CRT "Condition".

6.2.2 Trouble Notes:

6.2.2.1 Gas: In a new tube, continuing "getter" action may correct this. In an older tube (300 hours' use or more), replace CRT.

6.2.2.2 Cathode Interface: (Usually accompanied by gas). Check gate waveform at pins 3 & 8 of V840. If normal, CRT cathode is probably damaged. Replace CRT.

6.2.2.3 Spurious Emission: If serious, replace CRT.

6.2.2.4 Low Intensity: Check for gas. Check for normal operating potentials. If deflection sensitivity is abnormally high, check for +8650 v supply failure. Try new V820 (Check 4.1.3). If a new tube, see Step 6.4.

6.2.2.5 Intensity Modulation at 60 cps rate: Probably leakage within CRT. Try replacement.

6.3 GEOMETRY:

6.3.1 Geometry Check: Patch from Vert Sig Out to Trigger or Ext Sweep In connector. Turn Horizontal Display to "Delaying Sweep", turn Main Sweep Stability CCW (not into "preset") and Triggering Mode to any position except Automatic. Obtain triggered, Delaying-Sweep display of calibrator waveform at 2 msec/cm. Increase vertical deflection until top and bottom of square-wave are off screen. Advance intensity until vertical lines become visible.

Check to see that vertical lines near right and left-hand edges of graticule are parallel to the vertical graticule lines within 1° (±2/3 mm) anywhere inside the 4 cm viewing area of the graticule. Note in Cal Record if OK.

Reduce intensity, remove calibrator signal, and free-run Delaying Sweep. Position trace to top and bottom of graticule. Bowing should not exceed 1/2 mm within 10 cm graticule viewing limits. Note in Cal record if O.K.

6.3.2 Adjustment: Locate Geom Adj control on center bulkhead near F & I chassis above CRT. Set up Calibrator waveform display as above, and use Delaying Sweep Length control (red knob concentric with D.S. Time/Cm) to set sweep length to just 10 cm, entirely within graticule. Set Geom Adj for minimum bowing of vertical lines. Within the range available for optimum Geometry, adjust for minimum flare (haze) in center of CRT. Recheck horizontal bowing as in 6.3.1. Final setting should reflect best compromise between vertical bowing, horizontal bowing and flare. Note in Cal Record if adjustment is required.

6.3.3 Troubleshooting:

6.3.3.1 Insufficient Geom Adj Range: Check vertical sensitivity and vertical plate shield voltage as in 6.4. See that Geom Adj provides proper range of voltages (225-350 v). Recheck HV supplies. Position spot to CRT center and measure deflection plate voltages. All should be near 300 v. Try new CRT.

6.3.3.2 Geometry Drifts: If Geometry changes over a short period (a few minutes or hours) without any apparent external cause (average applied potentials, etc.) there may be a "floating" internal structure, or charging of the CRT envelope. Remove CRT, wash thoroughly with soap and water, and--when completely dry--reinstall. If drifting geometry persists, replace CRT.

6.4 IF NEW CRT IS INSTALLED:

6.4.1 Operation Check:

6.4.1.1 Repeat Steps 6.1 (Alignment) and 6.2 (Condition).

6.4.1.2 Reset Geometry (6.3).

6.4.1.3 Check and Log Vertical Deflection Factor: With no vertical signal input, position trace or spot to the top graticule line. Using voltmeter, measure the voltage difference between upper and lower vertical plates .

(CAUTION: These plates are at about +300 v).

Now, position trace or spot to bottom graticule line (reverse meter polarity or leads) and read voltage difference. Add the two voltage readings. The total should be 25-27 v (6.25 to 6.75 v/cm). Divide total by 4 and log result on Cal Record.

6.4.1.4 Check and Log Vertical Plate Shield Voltage: (Turn off scope to remove F & I shield above CRT at rear of scope). Locate the junction of R863 and R864, the third notch from the outside on the next-to-rear ceramic strip. Measure and log voltage at this point (290-310 v). This potential affects both Geometry and vertical sensitivity.

6.4.1.5 Followup: Be sure step 7, 11, 13 and 15 are completed following CRT change. Otherwise, instrument calibration may be off by as much as 10%.

6.4.2 TROUBLESHOOTING:

6.4.2.1 Deflection Factor Off: This is most critical in instruments S/N 101-9291, less so in later scopes. Recheck HV supplies. If all potentials are normal, try changing the vertical plate shield voltage within the 290-310 v range. Shunt R863 to increase deflection factor (reduce sensitivity), or R864 to decrease deflection factor (increase sensitivity). Use shunt resistors between 470 k and 2 meg. Select final values for R863/864 for correct deflection factor and best Geometry.

> NOTE: Total resistance of R863/864 must remain between 225 k and 275 k, and shield potential between 290-310 v. If these limits are exceeded, linearity and risetime problems may result in later steps.

6.4.2.2 Low Intensity: A CRT after prolonged storage may show low intensity due to cathode deterioration with disuse. To reactivate cathode, operate the instrument for 3 or 4 hours at 125 line volts, followed by 24 hours' continuous operation at 120 line volts, drawing normal beam current (defocus trace and position well off-screen to avoid phosphor damage). This should restore normal cathode activity.

7 MAIN VERTICAL AMPLIFIER - INITIAL ALIGNMENT.

7.1 VERTICAL AMPLIFIER PRECHECK:

7.1.1 Microphonics Check: Install Type P, Type TU-1, or TU-2 plug-in in scope under test, to eliminate possible erroneous microphonic indications. Free-run main sweep at slow rate, and rotate the Delaying Sweep Time/Cm control rapidly through its range back and forth. The trace should show no microphonics of the ringing type. Non-ringing microphonics should not exceed 2 to 3 mm. Log in Cal Record if OK. Otherwise, proceed with 7.1.2.

7.1.1.1 Troubleshooting: Replace input amplifier tubes (6AW8's or 12BY7's) with new, checked* tubes. Check to see that all screws in and about the vertical amplifier are tight. Check for possible microphonics in power-supply 6AU6 tubes. Tap other vertical amplifier tubes lightly for microphonic indication. Occasionally, wirewound resistors of the noninductive type will show "microphonic" shorted turns. Be sure to check for contact resistance in tube sockets before undertaking any major component changes, however. Work tubes about in their sockets, watching for trace-shift. In an instrument that has been in use for some years, some contact resistance is normal, but can be reduced by continued manipulation of the tube in the socket.

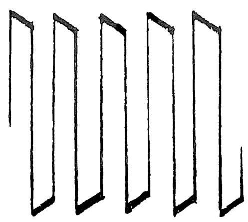


Fig. 7-1. Severe "tilt" to Calibrator waveform injected through EP53A, indicating defective input amplifier tubes. (Sweep: 2 msec/cm.)

7.1.2 Input Stage Check: Install voltage-measurement plug-in. Center free-running trace and measure bias in input stage of main vertical amplifier. Measure between grid and cathode of each input stage tube (6AW8 or 12BY7A). If less than 1.0 volt or more than 2.0 volts, replace both input amplifier tubes*. If this does not correct the bias, check to see that the DC level at pins 1 and 3 of the interconnecting socket are at +67 v ±1 v. If not, use another plug-in.
Now, install Type EP53A Gain Adj adapter between the plug-in and the oscilloscope. Apply 0.2 v of Calibrator waveform to the EP53A banana jack, using banana patch lead. Adjust triggering controls for stable display at 2 msec/cm. Check for slope of top of waveform (Fig. 7-1). Top of waveform should be substantially flat. Note apparent condition of tubes in Cal Record.

If any appreciable slope is visible, replace input amplifier tubes *and repeat 7.1.

*For 545's S/N 101-9291, use checked 6AW8's, Tektronix, Inc. P/N 157-039. For serial numbers 9292-up, use checked 12BY7A's, Tektronix, Inc. P/N 157-053. Always replace both tubes at the same time, and always use two tubes with the same subgroup number (between 1.0 and 2.0) stamped on the label. In emergency, unchecked tubes may be used, if selected for low microphonics, gain and balance. It may be necessary to go through a dozen or so tubes to find a usable pair, however.

7.1.3 Cathode Interface Check: Install Type (53/54) P Plug-in and pre-set front-panel controls as follows:

Stability	Triggerable	Horizontal Display	Main Swp Norm.
Triggering Level	0	Trigger Slope	+Int
Time/Cm	.1 μsec	Triggering Mode	AC Fast
Multiplier	2	Coil Current	On
Magnifier	Off	Amplitude	3 O'clock

Install viewing hood. Adjust Triggering Level control for stable display with trigger-point about 1/2 cm ahead of rising portion of waveform (See Fig 7-2). Adjust Amplitude control for about 3 cm display, and position leading edge near center of graticule.

7.1.3.1 Driver Stage Check: Examine the waveform for a sharp dip immediately following the leading edge (See Fig 7-3), indicating possible defect in driver-stage tubes. Adjust line voltage to 105 v for 10-15 seconds, then to 125 v. If the "notch" appears to change amplitude with changing line voltage, try replacing the driver stage tubes (in early instruments, V1050 and V1052; in later instruments above s/n 9291, V1033 and V1043). Return line voltage to 117 v.

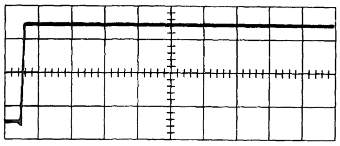


Fig. 7-2 P Unit Display at 0.2 μsec/cm.

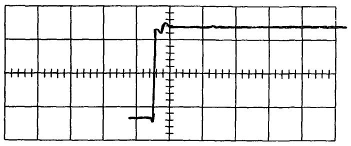


Fig. 7-3 Effect of defective driver-stage tubes, 0.2 μsec/cm.

7.1.3.2 Input Stage Check: Reduce sweep speed to 0.5 μsec/cm. Examine waveform for slope in first cm following leading edge (Fig. 7-3). Check for effect of line-voltage change on slope. If line-voltage affects slope, try replacing input amplifier tubes (6AW8's or 12BY7A's) with aged and checked tubes from same subgroup. If tubes are replaced, repeat Step 7.1.

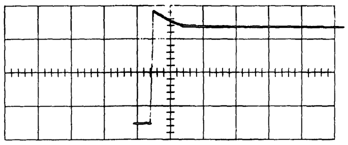


Fig. 7-4 Effect of "cathode interface" in V.A. 0.5 μsec/cm.

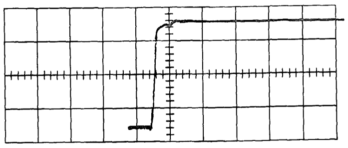


Fig. 7-5 Rolloff defect in D.A. tubes. 0.5 μsec/cm.

7.1.3.3 Distributed Amplifier Tube Defects: If tube replacement in 7.1.3.2 does not eliminate changes in slope (Fig. 7-4 or 7-5) with line-voltage change, distributed amplifier tubes (6CB6's or 6DK6's) will require replacement. (Do not mix tube brands.)

Now, turn P-Unit "off". Center the trace and check voltage at each suppressor grid in the distributed amplifier for +175 v. Replace any tube which does not read at least 165 v at the suppressor grid. (If tube replacement does not correct voltage, check suppressor bypass capacitors.)

7.2 VERTICAL BALANCE:

NOTE: It will be necessary (where specified) to use a "resistive shorting bar", consisting of a 47-ohm 1/2 watt composition resistor attached to some convenient insulating handle, for shorting grids together. Use of clip leads or wires will introduce enough inductance to cause oscillation, usually at a frequency far beyond the amplifier bandpass. These oscillations are rectified in the amplifier and appear on the CRT as DC level changes, making balance measurements impossible. The resistor lowers the Q of the inductive circuit below the point where oscillations can occur.

7.2.1 Overall Balance: Free run the main sweep at 1 msec/cm or faster. Locate CRT electrical center by shorting the vertical deflection plate pins together (NOT to ground). Note graticule position of electrical center and remove jumper. Now position the trace back to CRT electrical center, using vertical position control.

Now, use the resistive shorting bar (if test load unit is used, press "zero reference" button) to jumper the main amplier input stage grids together. Connect the shorting bar between pins 1 and 3 of the plug-in interconnecting socket. Log trace displacement from CRT electrical center in Cal Record. If 1 cm or less, skip 7.2.2 for the moment (it may be necessary to come back to this later). If more, complete 7.2.2.

7.2.2 Vertical Balancing:

7.2.2.1 Distributed Amplifier Stage: Use a short cliplead to jumper the distributed amplifier grid lines together (the two distributed lines running outside the rows of tube sockets, connecting with pins 1 of the DA tubes).

(CAUTION: Do not short to ground).

If trace-shift from electrical center is 2 mm or less, log in Cal Record and proceed with 7.2.2.4. If more , complete 7.2.2.2-7.2.2.3.

7.2.2.2 D.A. Bias: Again jumper DA grid lines. Use DC voltmeter to measure grid-to-cathode bias for each tube pair. For each pair, measure from jumper to either cathode (pin 2) of each pair. For S/N 101-9291 (and 9292-11691 with original tubes*) bias should be 0.9-1.6 volts. For later instruments, 1.0 v minimum to 2 v max. Replace one or both tubes of each out-of-tolerance pair. For S/N 101-9291, use check 6CB6's, Tektronix p/n 157-037. For S/N 9292-up, select "raw" 6DK6's, but see* below. Log high and low bias values in Cal Record.

*6DK6 design changes in late 1958 require modification of instruments S/N 9292-11691 to use the new-style tubes. Modification kit 040-191 ($1.80) changes cathode resistors in the 12BY7 stage to provide 1.0 v minimum bias on output stage, and permits use of old or new 6DK6's. To check doubtful instrument, examine R1016 & R1017--if 3k (5w5%) and 10 k (8w 5%), the instrument has already been modified.

7.2.2.3 D.A. Balancing: After selection of tubes (if necessary) for proper bias, recheck 7.2.2.1. If trace shift is still greater than 2 mm from CRT electrical center, tubes of a pair can be "swapped across" to achieve balance. If tubes are swapped between pairs, or if further tube replacements are required for balance, repeat 7.2.2.2. Log final balance point, and reposition trace to this point.

If imbalance persists, check resistances of reverse termination network (plate loads) for symmetry (±2%). Check for opens or shorts in individual suppressor-grid networks, and for partial short to ground on one side of delay line.

TUBE REPLACEMENT NOTE: Do not reject 6CB6 or 6DK6 tubes because of a slight blue glow (noticeable only in a darkened room) outside the plate area. This is not necessarily an indication of gas, but is caused by glass fluorescence where the envelope is struck by the accelerated electron beam, and is normal in good tubes. If in doubt, check tube in conventional gas-detection circuit. Tubes should not be rejected for heater-cathode leakage unless it is less than a few thousand ohms. These tubes normally show slight leakage.

7.2.2.4 Driver Stage Balancing: Use the resistive shorting bar to jumper the grids of the driver cathode-followers. Select tubes if necessary for not more than 1/2 cm trace shift from DA imbalance point. In instruments above S/N 9291, both cf stages must meet this specification. For optimum balance with minimum tube selection, use Type ECC88/6DJ8 or E88CC/6922 instead of Type 6BQ7A. If imbalance persists, check cathode resistors for symmetry (±10%), and check plate voltages, filament lines, etc.

7.2.2.5 Input Stage Balancing: Position trace to CRT electrical center, and again jumper input stage grids as in 7.2.1. Trace shift should be 1 cm or less. Install new checked input tubes (6AW8's p/n 157-039 or 12BY7A's p/n 157-053 -- See footnote, 7.1.2) if necessary. If imbalance is less than 1/2 cm from driver-stage imbalance point, but more than 1 cm from CRT electrical center, try swapping positions of the input tubes before replacing with new ones.

If input stage imbalance persists, check values of plate load resistors for symmetry; also cathode resistors. Check components in DC Shift compensation networks(tiny 68 k resistors connected to input stage plate loads, etc.).

7.3 LINEARITY: Install Dual-Trace plug-in. Free run main sweep at 10 μsec/cm. Position trace to top and bottom of visible scan. If necessary, remove graticule cover and use white nylon cam to adjust graticule so ruled portion is exactly centered in area of usable scan.

7.3.1 Compression (linearity) Measurement: Set vertical Volts/Cm to 5, and display exactly 2 cm of calibrator waveform (adjust Variable volts/cm if necessary), centered vertically. Position the display up to the top graticule line and note any compression or expansion (Spec: 0.5 mm max). Now, position the display so it "rests" on the bottom graticule line, and note compression or expansion. If within spec, log measured figures on Cal Record.

7.3.2 Troubleshooting:

7.3.2.1 Compression at Top and Bottom; Expansion at Top and Bottom: Check to see if compression or expansion is the same at the edges of the graticule as at the center. If not, reset Geometry (6.3). If compression is uniform across CRT, recheck DA Bias (7.2.2.2) and CRT Deflection Factor (6.4.3-6.4.4). Recheck regulated power supplies (2.3), especially +350 v supply. Check DC level at pins 1 and 3 of plug-in connector for 67 ± 1 v.

7.3.2.2 Compression and Expansion: If trace shows compression in in one direction and expansion in the other, recheck vertical balance (7.2). Complete steps 7.2.2.1 through 7.2.2.5 if skipped before. If balance and bias are within tolerance, try swapping CRT Vertical deflection plate leads for inverted display. If directions of compression and expansion are reversed, trouble is in vertical amplifier. If they remain exactly as before, try replacing CRT, following procedures in 6.4. Try another plug-in.

7.3.2.3 Persistent Troubles: If CRT change does not correct trouble, try exchanging complete vertical tube complement from known-good instrument of same serial range. Check screen and filament circuits, vertical termination network, etc. Check for partial short to ground in delay line. For instruments S/N 9292-11691, check to see if modification kit 040-191 has been installed to accomodate new type 6DK6 tubes. In modified instruments, R1016 and R1017 (in input stage cathode circuit) will be 3 k and 10 k respectively. See 7.2.2.2 and footnote. Install mod kit if necessary. In rare cases compression has been caused by a bad CRT shield. If all else fails, try installing a new shield.

7.4 D.C. SHIFT:

7.4.1 D.C. Shift Check: Use battery, or ohmmeter range of VOM to deflect free-running trace 4 cm. Watch trace closely for 5-10 seconds. If it drifts from its first stopping point, log amount and direction of drift in Cal Record under "Initial" (re-check measurement by noting drift during 5-10 seconds after removal of DC voltage). If this drift is 1/2 mm or less, proceed to 7.5. If more than 1 2 mm, complete 7.4.2.

7.4.2 D.C. Shift Compensation: Locate D.C. Shift Comp. control on main amplifier chassis. Repeat 7.4.1, making small adjustments of this control. D.C. shift itself is a slow decrease in deflection; over-compensation will result in a slow increase in deflection. Set compensation for as close to zero shift as possible. Recheck at slow (2 sec/cm) sweep. Log final shift and direction in Cal Record under "Final".

7.4.3 Troubleshooting: The D.C. shift compensation network consists of the small 8.2 k resistors connected to the terminated end of the output plate lines, the control itself, four 75 µf electrolytic capacitors, the two 47 k resistors between capacitor sections, and the small 68 k resistors connected to the plate load resistors of the input amplifier stage.

7.4.3.1 Inadequate Range of Control: Check the small resistors first for correct value: They are likely to be damaged by any severe power supply aberration. Check the electrolytic capacitors for leakage or change of value. See that there are no open spots in the control.

7.4.3.2 Trouble Not in Compensation Circuit: If all compensation network components are within tolerance, it may be necessary to replace vertical amplifier tubes. If these are replaced, be sure to repeat step 7.1, 7.2, and 7.3. Also recheck proper operation of regulated DC supplies and vertical amplifier filament circuits.

7.4.3.3 Wrong Time-Constant: (S/N 9292 and up): If new General Electric 6DK6's are used and DC shift compensation appears to have the wrong time-constant (irregular drift of trace), replace 8.2-k resistors with 6.8 k 1/4 watt 10% resistors. General Electric and other tube brands should not be mixed in the distributed amplifier.

7.5 DRIFT WITH LINE VOLTAGE CHANGE:

7.5.1 Drift Measurement: Install Type P or Type TU-1 or TU-2 plug-in and center free-running trace with no input signal, and line at 117 v.

Reduce line voltage to 105 v and watch for slow drift of trace due to filament voltage change. Now increase line voltage to 125 v. If resulting drift is less than 1 cm* log in Cal Record and proceed to Step 7.6. If more than 1 cm, complete Step 7.5.2.

7.5.2 Troubleshooting: Drift may not be due entirely to vertical amplfier tubes. Try steps below in order given.

(a) If tubeless plug-in was not used for 7.5.1, try other plug-in types, to see if drift was due to plug-in.
(b) Recheck for voltage regulation of DC supplies and HV supplies (2.3.1.3 and 4.1.2).
(c) Recheck vertical amplifier balance, and complete balancing procedure (7.2.2).
(d) Replace input amplifier tubes. Repeat 7.1-7.4 and 7.51.
(e) Replace driver cf's; repeat 7.2-7.4 and 7.5.1.
(f) Replace DA tubes with known-good set. Repeat 7.2-7.4 and 7.5.1.

*Original factory specification was 1/2 cm. This should be achievable with new VA tubes.

7.6 VERTICAL SIGNAL OUTPUT & TRIGGER PICKOFF.

7.6.1 Amplitude and Waveform Check: Obtain 2 cm calibrator waveform display on scope under test. With test scope, measure output at Vert Sig Out connector on front panel. This should be 3 volts minimum, ±1.5 v from ground potential (AC-coupled circuit). Check waveform for aberrations as display is positioned up and down. If no aberrations are noticeable, log output (in volts/cm) on Cal Record and proceed with 7.7.

7.6.2 Troubleshooting:

7.6.2.1 Insufficient Output: (S/N 101-9291) Try replacing V1050 and V1052. If these tubes are replaced or returned to opposite sockets, recheck 7.2.4. Try replacing V1060 and 1066 (recheck 7.2.2 and 7.2.3). Trace signal back through V1050, 1052 and 1066 to isolate defective stage; check components in plate and cathode circuits.

(S/N 9292-up): Replace V1223. If this is sufficient, no previous steps need be repeated. If necessary, replace V1064 and/or V1054 (repeat 7.2.2 and 7.2.3). Trace signal back through both halves of V1223 to 1064 and 1054 to isolate defective stage; check for faulty components in plate and cathode circuits.

NOTE: In later instruments, R1064, (V1064 plate load) was replaced by resistively-wound coil L1064. Resistance of this coil is approximately 2 k.

7.6.2.2 Excessive Noise: Check noise level at grids of pickoff tubes; compare signal-to-noise ratio with Vert Sig Out. If pickoff circuitry is introducing noise, replace tubes and components as necessary. If VA tubes are replaced, repeat necessary steps as noted in 7.6.2.1.

NOTE: Excessive noise output will seriously affect low-frequency sine wave triggering in "internal" triggering. Correction will be necessary for proper trigger-circuit operation.

7.7 GAIN SET:

7.7.1 Maximum Gain: Install EP53A Gain Adj Adapter between plug-in and scope, or install TU-1 (or TU-2 set to 1:1) Test Load Unit. Apply 200 mv of calibrator signal to banana jack on EP53A or to TU-1 or TU-2 input. Turn Gain Adj control for main vertical amplifier (facing down on amplifier chassis) full clockwise. Log vertical deflection. If more than 2.2 cm (10% reserve gain) proceed with 7.7.2. If less than 2.2 cm but more than 2 cm, the scope may be usable for some purposes, but difficulty may be encountered in making proper risetime and bandwidth (Step 15). If less than 2 cm proceed with 7.7.3.1.

7.7.2 Set Gain: If maximum gain is adequate, reduce setting of Gain Adj control for exactly 2 cm deflection with 200 mv calibrator input. (If TU-2 is used, set toggle switch to "250:1" and apply 100 v from calibrator. Reduce setting of Gain Adj for exactly 4 cm deflection).

7.7.3 Troubleshooting:

7.7.3.1 Insufficient Gain: Check stage gains with a regular voltage-measurement plugin in the instrument under test, to assure even phase-splitting ahead of the main vertical amplifier input. Measure amplitude at each grid, comparing gain against the table below.

Amplifier Stage	Gain	
	Min	Normal
12BY7A or 6AW8 Input Amp (Gain Adj Clockwise)	4 - 4.5	5.5 - 6
6BQ7/6DJ8 CF Stage*	0.7	0.7
Distributed Amp (6CB6's or 6DK6's)	20 - 22	22 - 24

*Above S/N 9292, 0.7 gain is total for both CF stages.

If both input and output stages are at or near minimum gain, tubes in one or both stages may require replacement.

If overall amplifier gain is 70 or more, the trouble is probably not in the amplifier, and may be in CRT sensitivity. Recheck HV supplies (4.1) and Deflection Factor (6.4).

If VA tubes are changed, be sure to repeat all parts of Step 7. If tube-change does not provide correct gain, check plate load resistors, screen potentials, decoupling networks, filament lines, etc. Also check calibrator accuracy (Step 8), and input DC level (7.1.2).

7.7.3.2 Gain Setting Unstable: Check Gain Adj control for intermittency. Check for changes in input stage grid DC level. Check decoupling circuits, electrolytic capacitors and DC shift network components (7.4.3). Monitor for power supply fluctuations, and intermittent plate or cathode resistors. Try using Calibrator signal from test scope, in case intermittency is in calibrator. Check VA tubes for gas (but see note in 7.2.2.3).

8 CALIBRATOR DIVIDER.

8.1 ACCURACY CHECK: Remove EP53A Gain Adj Adapter (if used) and install Dual-Trace (C or CA) plug-in. (For greatest accuracy, use Type Z. Procedure below is for dual-trace unit only, however.) Present controls as follows:

Volts/Cm:	.05	Horizontal Display:	Main Sweep
Variable:	C.W.	Time/Cm:	10 µsec/cm
Mode:	A only	Stability:	CW
AC-DC:	DC (Important)	Triggering Mode:	AC Slow

Apply 0.2 v from Calibrator to plug-in input. Adjust plug-in Gain Adj for exactly 4 cm deflection. Now, turn Volts/Cm to 20 and calibrator output to 20 v. Position top line of 1 cm display to the bottom graticule line (bottom line of display invisible) and turn calibrator to 100 v. Top line of display should be within 1 mm of top graticule line.

Now, step calibrator output down as volts/cm switch is stepped clockwise. Top line of display should coincide with top or next-to-top graticule line ±1 mm at each step. If coincidence does not occur at .05 v/cm, repeat procedure. If necessary, recheck DC Shift Compensation (7.4).

Now, check 100 mv calibrator output (2 cm display). Log greatest discrepancy between plug-in attenuator and calibrator divider in Cal Record. If 2% or less, proceed to Step 9. If more, complete 8.2.

8.2 ERROR CONFIRMATION: If discrepancy in 8.1 was less than 4%, both calibrator and plug-in dividers may actually be within tolerance. Repeat 8.1, using Channel B of plug-in. Recheck plug-in and calibrator against test scope calibrator and input attenuator. Log any confirmed error in calibrator divider in Cal Record. If over 2%, complete 8.3.1.

8.3 TROUBLESHOOTING: Because of the calibrator divider design, it would take a large error in any one resistor to produce a significant output error (exception: 0.2 v output). If all steps are "off" except 0.2 v, check for proper grounding of the switch before replacing R691. A one-ohm resistance in the switch ground-return path will produce 2.5% error at 0.2 v.

8.3.1 Error Correction: (Method 1) Use precision differential voltmeter. Turn calibrator "off" and measure DC voltage drop across each resistor, turning Calibrator switch to "50 v" to measure drop across R683, to "20 v" for R684, etc., for normal compensated load.

(Method 2) Turn scope off. Use resistance bridge to measure value of each resistor. Turn Calibrator Switch to ".2 v" for all measurements. If R694 is suspected, it must be removed from the circuit for measurement. V246 should probably be removed during measurements to eliminate possible heater-cathode leakage as a cause of measurement error.

NOTE: If 0.2 v calibrator output is changed or affected gy correction procedure, repeat Step 7.7 (Gain Adj).

8.3.2 Erratic Output: Try tightening the mounting nut on the calibrator switch; recheck for ground-return or contact resistance as switch is operated. Replace V246. Check for intermittency in Cal Adj control. Check 1/4 ohm resistor R698. Repeat Step 3 after tube replacement or circuit repairs; also 7.7.

8.3.3 Vertical Drift After Switching in 8.1 Procedure: Repeat DC Shift Compensation, Step 7.4.2.

9 TRIGGER CIRCUITS, MAIN SWEEP.

9.1 PRELIMINARY CHECKOUT: Install Type (53/54) K or L plug-in. Set front-panel controls as follows:

Control	Setting	Control	Setting
Stability	Free-run (CW)	Multiplier (Red)	Clockwise
Triggering Level	Clockwise	Triggering Mode	DC
Time/Cm	1 msec/cm	Triggering Slope	+Int
Multiplier (Black)	12-5	Horizontal Display	Main Sweep Normal

	Procedure	Interpretation
9.1.1	Sine Wave Triggering, DC Mode: Set vertical Volts/Cm to 10, and patch from the 6.3 v AC connector to the vertical input*. Center display vertically. Back off Stability control until the display disappears, then about 5° more. (a) Now, bring up Triggering Level control until display is triggered, and triggering point (start of sweep, at left) is at the graticule centerline. Note Triggering Level position (+ or - from "0"). (b) Now switch Trigger Slope to -Int and again note Triggering Level position required to center the triggering point.	If points (a) and (b) are not the same, Trigger Level Centering will require adjustment. If both on the same side of "0", Int Trig DC Level has drifted, will require resetting. If no triggering, Sensitivity may be too low, or tube replacement may be required. If display is "double", Sensitivity is too high.
9.1.2	AC Slow: Turn Triggering Mode to AC Slow. Set Triggering Level for stable, triggered display. Rotate the red Multiplier knob through its range, watching for erratic triggering at any setting.	If DC Mode is OK, but AC Slow won't trigger sweep, C3 may be leaky, or tubes may require replacement (gassy). Erratic triggering in mid range may indicate defective Triggering Level pot.
9.1.3	Automatic: Switch Triggering Mode to Automatic (or "AC Auto"). See that triggering occurs on the proper slope for +Int and -Int settings. Remove input and increase Time/Cm to 10 µsec/cm, Black Multiplier knob on "1". A dim, unmodulated trace should be visible.	Erratic triggering or bright trace at faster sweep indicates probable Preset Stability error. No trace without input indicates V20 is weak. No trace with input (normal triggering OK) is probably Preset Stability problem, possibly tube trouble.
9.1.4	Hum Check: With Triggering Mode still on Automatic (and no input to vertical) and sweep Time/Cm at 10 µsec/cm, switch from +Int slope to -Line. The dim trace should brighten very slightly.	If 9.1.3 showed dim trace in Automatic, but no brightening was observed in 9.1.4 (sweep repetition rate increased from 50 cps to 60 cps) there may be hum getting into the trigger circuits, tending to synchronize the free-running V20 action. This can also be caused by time-constant and gain changes in V20: Check for actual line-synchronization first.

9.1.5 Interpreting Results: If reliable triggering resulted in all steps above, trigger circuits will probably only require minor adjustment. If not, tube replacements may be necessary; however, try realignment first. Data in the right-hand columns above indicate probable trouble areas.

*If no deflection results, see 16.3. There should be about 2 cm (17.8 v p-p) display.

9.2 REALIGNMENT: Preset front-panel controls as follows:

Control	Setting
Stability	"Triggerable" (5° CCW from free-run)
Triggering Level	"0"
Time/Cm	1 msec/cm
Magnifier	Off
Multiplier (Black)	5
Triggering Mode	AC
Trigger Slope	+Ext
Horizontal Display	Main Sweep Normal

9.2.1 Triggering Level Knob Zero: Locate the junction of 470 k resistors R16 and R17 on the left side of the Trigger Slope switch. R16 comes from the wiper terminal of the Triggering Level pot. Use VTVM or test scope to measure voltage at this point. Adjust Triggering Level knob if necessary to set voltage at this point to zero ±50 mv. If Triggering Level knob is now off "0" on the front panel, loosen set-screw and reset knob on shaft for correct indication.

9.2.2 V8 Gas Check: With Triggering Level set as in 9.2.1 to measured zero, turn Trigger Slope switch from +Ext to +Int and note any change in DC reading at R16/17, using VTVM or test scope. Any level change of more than 200 mv indicates excessive gas in V8. Replace tube and repeat this step after warmup. For best results, replace with Type 6DJ8/ECC88 or 6922/E88CC instead of 6BQ7A. Repeat 9.2.1.

9.2.3 Adjustments:

9.2.3.1 Trigger Level Centering: Leaving Triggering Level at "0", clip a jumper from the junction of R16 and R17 to ground. Set Trigger Slope switch to +Int. Patch from 6.3 v AC connector on front panel to vertical input, and increase vertical gain as necessary to obtain triggered display.* Adjust Trigger Level Centering (on bracket above sweep deck) to obtain triggering for both +Int and -Int slope settings. Turn Trigger Sensitivity (on same bracket) full clockwise if necessary to obtain triggering.

9.2.3.2 DC Level Adj: Now, switch Triggering Mode to DC and adjust Int Trig DC Level Adj (just behind front panel) to restore triggered display.

9.2.3.3 Touch-Up: Turn Trigger Slope back and forth between +Int and -Int, adjusting Trigger Level Centering until triggering occurs at the same point on the graticule for both settings. Now, use Int Trig DC Level Adj to move this triggering point to the exact center of the graticule. Touch up Trigger Level Centering adjustment if necessary.

9.2.3.4 Trigger Sensitivity: Remove 60-cycle waveform and increase Time/Cm to 10 μsec/cm. Carefully increase Intensity until spot is just visible. Use vertical position control to move spot back and forth across the center of the graticule. One (dim) sweep should be triggered each time spot passes the center, in the upward direction only for +slope setting and in the downward direction only for -slope setting.

(9.2.3.4 continued on next page)

*If sensitivity must be increased above 5 v/cm, recheck for 17.8 v p-p output at 6.3 v AC connector. If ok, try experimental setting of Trigger Sensitivity and Trigger Level Centering before replacing tubes.

9.2.3.4 Trigger Sensitivity -- continued: If a bright burst of sweeps occurs as the spot passes slowly over the triggering point, or if sweep is triggered on both upward and downward passes for either slope setting, Trigger Sensitivity setting is too high. Advance Stability control until sweep just free runs with no vertical input, then back off just slightly. Advance Trigger Sensitivity if necessary, until double-triggering or burst-triggering occurs, as described above. Now, back off Trigger Sensitivity until neither aberration occurs as spot is positioned past triggering point on either slope setting. Then back off 10-15° further.
Reapply 60 cycle waveform, reduce intensity (and reduce Time/Cm setting if desired) and touch up Trigger Level Centering as in 9.2.3.3.

9.2.3.5 Preset Stability: In instruments equipped with this feature, turn Stability control counterclockwise into "Preset" switch position, turn Trigger Slope to +Line and Main Sweep Time/Cm to 10 μsec/cm. With no vertical input, a dim trace will appear if circuit is already in adjustment. Locate Preset Stability control throughout its range and note the settings for no trace (lockout), dim trace (triggerable) and bright trace (free-run). Set the control to the middle of the "triggerable" range.

9.2.3.6 Automatic: Set front-panel Stability control to "Triggerable" range (not necessary in later instruments with "preset" feature), turn Triggering Mode to Automatic (or "AC Auto"), Trigger Slope to +Int, and Time/Cm to 10 μsec/cm. A dim trace should appear, and should brighten very slightly when Trigger Slope is changed to +Line. Return to internal triggering and 1 msec/cm sweep, and apply 1 v of calibrator waveform to vertical input with vertical Volts/Cm at 10. A stable 1 mm display should result. See that stable triggering on the proper slope occurs in +Int -Int slope settings.

9.3 FINAL CHECKOUT: REMOVE JUMPER installed in 9.2.3.1, and increase Calibrator output to 2 v. Set Triggering Mode to AC Slow and adjust Triggering Level if necessary to obtain triggered display. At some Triggering Level setting near "0", it should be possible to switch back and forth from + to - slope and obtain stable triggering. Log the minimum size signal which can be displayed trigged on either slope without readjustment of the Triggering Level. Switch to AC Fast and repeat procedure. Switch to DC mode and reposition display as required for switchable triggering as above (minimum signal here will be larger than for AC slow because of the DC divider circuitry). Touch up circuits again if necessary, to meet the following specs:

Internal (Calibrator Wave-form):

AC Slow and AC Fast:	2 mm signal anywhere within graticule, switchable with Triggering Level at "0".
DC Mode:	2 mm signal within 2 mm of graticule center, switchable with Triggering Level at "0".

External (Calibrator Wave-form):

AC Slow, AC Fast:	200 mv signal, switchable with Triggering Level at 0.
DC Mode:	200 mv signal, switchable with Triggering Level slightly clockwise from 0.

Internal, 60 cps sinewave display:

AC Slow, DC: 5 mm signal, switchable with Triggering Level at 0.

CAUTION: It is not desirable to obtain triggering sensitivity in excess of specifications. Normal tube aging increases sensitivity of the shaper multivibrator (V20) and will cause erratic triggering on small noise components, particularly when the instrument is triggered from low-frequency sine waves.

9.4 H.F. SYNC:

NOTE: The HF Sync mode does not involve the trigger circuits outside of the Triggering Mode switch itself. It is checked at this point to provide easy Cal Record reference and to clear up any serious malfunctions in the sweep circuits prior to sweep calibration.

9.4.1 Performance Check: Turn Triggering Mode switch to HF Sync and Trigger Slope to +Int. Set main sweep Time/Cm to 0.1 µsec/cm (black Multiplier knob on "1") and Magnifier on. Display 2 cm of 30 mc sine wave from Type 190A Sine-Wave Generator, and adjust Stability control in the "free-run" range for synchronized stable display (3 cycles each 5 cm). At some position of the Stability control, a stable display should be obtainable with not over 1 mm horizontal trace width (jitter due to hum & noise). Log HF Sync performance in Cal Record.

9.4.2 Troubleshooting: Sweep generator tube replacement will usually be required to correct excessive jitter or instability. Trigger circuit tubes will not affect HF Sync operation except through stray coupling (very slight effect on sync when Triggering Level knob is moved).

9.4.2.1 Excessive Jitter, No Sync:

(a) Recheck regulated power supplies for excessive ripple (2.3.1.2).
(b) Try replacing V37 and/or V43 (Stability CF, Trigger Gate).
(c) Try replacing V54 (Holdoff CF)
(d) Recheck trigger pickoff circuits (7.6); try tube replacements.
(e) Replace V58, V70, V80, V85, V90 and/or V73 as necessary.

9.5 TROUBLESHOOTING THE TRIGGER CIRCUITS:

9.5.1 Erratic Triggering on Small Signals: Check for excessive noise in internal trigger pickoff system (See 7.6). Triggering will normally become erratic, in Automatic mode, on signals below 1/2 mm in amplitude. Be sure erratic triggering is not due to RF pickup in unshielded patch lead. Use coaxial cable if necessary.

9.5.2 Double Display of Low-Frequency Sine Waves: Trigger Sensitivity too high; Trigger Level Centering mis-set; excessive noise in V8 or trigger pickoff circuits (try new V8; recheck 7.6); defective V20.

9.5.3. Insufficient Range, Trigger Sensitivity or Trigger Level Centering: Defective V8 or V20. Possibly capacitor leakage or resistor defect.

9.5.4 Triggering Level Zero Shift: If voltage at R16/R17 tends to drift without the cliplead to ground, replace V8; check Triggering Level pot for intermittency. See if voltage at junction of R1 and R2 (Int Trig DC Level divider, on front of first switch wafer) is constant. Measure with scope or VTVM. With trace centered, this should be 0 v ±100 mv. Readjust Int Trig DC Level Adj if necessary, and repeat 9.3. If tube replaced, repeat 9.2

9.5.5 Shift of Apparent "Zero", Int to Ext: Gassy V8.

9.5.6 Automatic: Bright Trace Without Input: (a) Preset Stability mis-set. (b) Excessive noise in pickoff or V8 circuits. (c) C20 leaky or partially open, R30 defective. (d) Insufficient holdoff: Check Step 14. (e) Excessive sweep waveform coupling into V8: Check +225 v and other regulated power supplies for sweep waveforms & noise (2.3.3.2). Automatic mode will show normal bright trace at slow sweeps; its normal 50-cycle repetition rate provides a dim trace only at fast sweep speeds. Check repetition rate with test scope with and without main sweep running.

9.5.7 Excessive Display Jitter: If calibrator waveform display exhibits any visible horizontal jitter, check to see if jitter is the same at the left as at the right of the trace. If so, either power-supply ripple is excessive or hum is being introduced in the sweep generator or the horizontal amplifier. If left-hand side is jitter-free and right side of display shows jitter, trouble is in the sweep generator (probably V80). Jitter of low-frequency sine-wave triggering point (use frequency other than 60 cycles) indicates hum in trigger circuits.

NOTE: Always complete trigger realignment procedure (9.2) whenever trigger tubes are replaced. If possible, use aged tubes or allow tubes to age-in several hours before final realignment, for most stable adjustment. Further use of Type 6BQ7A tubes is not recommended if Type ECC88/6DJ8 or 6922/E88CC tubes are available. For best results, do not attempt other type-substitutions. A good "aged" replacement for V8 is V73 (Gate & Sawtooth Output CF's). For instruments using Type 6U8A as V20, V155(Delaying Sweep Gating M.V.) will provide a good aged replacement. V73 and V155 are not particularly critical as to normal variations in tube characteristics and may be replaced with "fresh" tubes without affecting instrument operation or calibration. Correct performance of these circuits should be verified, however, if new tubes are installed.

9.6 TROUBLESHOOTING ASSOCIATED CIRCUITS: Some triggering problems may be due to defects outside the trigger circuits themselves. In addition to steps below, also see troubleshooting tips for Steps 11 and 12.

9.6.1 Stability Control Has No Effect: Make sure Horizontal Display switch is functioning normally and is set to Main Sweep Normal. Try replacing V43, then V37. Check for normal voltage control range at Stability control wiper (0 to -150v), at V43A grid (-43 to -60v) and at V58A grid (-40 to -50v). See Steps 12 and 13.

9.62 Stability Control Setting Too Critical: If the "triggerable" range of the Stability control seems too narrow, this is usually due to weak V20. Try replacement; check for minimum 6 v switching waveform output at pin 6 (a more convenient check point is the switch side of C58, the 27 pf capacitor from the Triggering Mode/Slope switch to V58A). If R32 is out of tolerance in either direction, triggering difficulties may result. Check R44 and R45 for "open"; or R47 for short. For further troubleshooting in the Sweep Generator, see Steps 11 and 12.

10 TRIGGER CIRCUITS, DELAYING SWEEP.

10.1 PRELIMINARY CHECKOUT:

10.1.1 D. C. Balance: Turn both sweep generators off. Turn Horizontal Display Switch to "Ext Sweep" and turn Magnifier on. Center beam with position controls, using beam-position indicator lights. Then bring up Intensity slowly until spot is visible. Rotate Stability or Ext Sweep Atten knob back and forth and note spot movement. If spot is stationary, input DC balance is OK. Note on Cal Record and proceed with 10.1.2. If not, complete 10.1.1.1.

10.1.1.1 DC Bal Adj: Locate Ext Swp Ampl DC Bal Adj near forward end of swingout chassis. Rotate Stability or Ext Sweep Atten as in 10.1.1, and set Ext Swp Ampl DC Bal Adj for no spot motion as the front panel control is rotated.*

10.1.2 Performance Check: Turn Magnifier off, reduce Intensity setting and turn Horizontal Display Switch to "Delaying Sweep". Set other front panel controls as follows:

Stability or Ext Sweep Atten	5° CCW from free-run.
Time/Cm or Delay Time	5 msec/cm
Delaying Sweep Triggering Level	"O"
Atten (Toggle Switch)	X 1
Slope (Toggle Switch)	+
Delaying Sweep Length	CW
Volts/Cm (Plug-In)	20

Patch from 6.3 v AC connector to plug-in input, and from Vert Sig Out to Trig or Ext Swp In. Adjust Delaying Sweep Triggering Level if necessary for triggered display (about 1 cm deflection). See if there is a single position of the Triggering Level control that will provide stable displays in both positions of the Slope switch. If not, proceed with Realignment procedure (10.2). Use Variable Volts/Cm to reduce display amplitude to determine minimum "switchable" 60-cycle display. If display is still switchable with the Slope switch, with Variable Volts/cm CCW, the trigger circuits are in excellent condition. If switchable condition obtains with Triggering Level at "O", realignment steps may be skipped, and Final Checkout figures logged (10.3).

*This adjustment provides optimum balance for using the External Sweep Amplifier as such, but not always for maximum trigger sensitivity when these circuits are used to trigger the Delaying Sweep. If use of external horizontal inputs is not anticipated, and optimum Delaying Sweep triggering balance is required, see "Alternate DC Bal", Section 10.2.4.

10.2 REALIGNMENT: (Remove patch from Vert Sig Out to Trig In.)

10.2.1 V113 Gas Check: With controls as in 10.1.2, use test scope to measure voltage at the center (wiper) terminal of the Triggering Level pot (the section nearest the front panel). Adjust the Triggering Level knob until this is 0v ± 100 mv. Now, measure the voltage at the opposite end of 1 meg resistor R107, which connects from this wiper terminal to the Horizontal Display Switch and 100 k resistor R108 and .001 µf capacitor C108. If the voltage here is substantially different from that at the wiper terminal (gas current), select 12AU7's for V113 for minimum drop across R107. Now, set Triggering Level knob for exactly 0v at the switch end of R107.

10.2.2 Triggering Level Knob Zero: Without disturbing settings in 10.2.1, check position of Delaying Sweep Triggering Level knob. If displaced from "O", loosen set-screw and reposition index to "O" when the voltage at R107/R108 is exactly "O".

10.2.3 Gain Check, V120: Turn Horizontal Display to "Ext Sweep"; apply 100 mv of Calibrator waveform to Trig or Ext Swp In and turn Stability or Ext Sweep Atten clockwise. Use test scope, AC-coupled, to view waveform at cathode, pin 7 of 6U8A, V130. There should be at least 800 mv, and the waveform should be free of any ripple modulation. Replace V120 and/or V130, V113 as necessary. If V120 is replaced, use Type ECC88/6DJ8 or 6922/E88CC if possible, instead of 6BQ7A.

10.2.4 Alternate DC Bal Set: Return controls to positions used in 10.1.2, and restore patch connections for 1 cm display of 60 cycle waveform. Switching Slope switch from + to -, adjust Ext Swp Amp DC Bal Adj so that switching occurs at the same point on the graticule for either slope. Compare this setting with that obtained by the method in 10.1.1. If trigger point separation does not exceed 1 or 2 mm with balance set as in 10.1.1 (DC imbalance as in 10.1.1 about 2 mm shift), final setting may be at either point, depending on whether optimum triggering convenience or optimum balance for external horizontal input applications is desired. If separation of the two "balance" points is excessive, further selection of V113, V120 or V130 may be desirable.

10.3 FINAL CHECKOUT:

Set up front panel controls as in 10.1.2, except set Atten toggle switch to X 10. Patch 60-cycle waveform to vertical input and Vert Sig Out to Trig or Ext Swp In. Log minimum display amplitude (mm) allowing slope-switching without resetting of Triggering Level pot, and absolute minimum display amplitude, disregarding "switchability". Repeat with calibrator waveform display. Remove patch from Vert Sig Out and patch Calibrator directly into Trig or Ext Swp In; log minimum voltage input required for stable triggering.

Specs:	Internal Switchable	1.5 cm	(Atten X 10)
	Internal Minimum	0.5 cm	" " "
	External Minimum	1.0 v	" " "

10.4 TROUBLESHOOTING DELAYING SWEEP TRIGGER CIRCUITS: Most common difficulties in the Delaying Sweep trigger circuits should be corrected by the realignment procedure 10.2. If tube selection and balancing fail to correct poor triggering, proceed as outlined below:

10.4.1 Stability Control "Triggerable" Range Too Narrow: Check switching waveform at plate of V130B (pin 1) for 6v minimum. If OK, try replacing V140, V150, V172 or V155. Check for 3v minimum trigger spike, negative-going, at grid, pin 7, of V140. Check for proper stability control voltage range at pin 7 of V140 (-45 to -66v) and at pin 8 (-42 to -53v). Measure with DC meter.

10.4.2 Trigger Sensitivity Too Low: Recheck alternate balance 10.2.4 for excessive separation of two balance points. Measure values of R124 and R135; with no trigger input signal, check for proper proportional voltage drop across R132 and R133 (V130B grid divider). Check for possible voltage difference between pins 7 & 8 of V130; also between pins 3 & 8 of V120 (switch contact resistance). Measure R121 and R123; also R136. Check filament and screen lines.

11 SWEEP CALIBRATION.

NOTES: In all of the sweep calibration steps that follow, maximum accuracy and utility of the oscilloscope will be preserved by making all direct-display timing measurements over the middle eight centimeters of the graticule. Adjustable timing ranges then may be set to within 1/2% over this portion of the graticule, isolating any non-linearity area to the outermost two centimeters. Closer setting is also possible because of the greater resolution of the CRT over the center 8 cm.

References to the "second" marker, the "tenth" marker, the "1 cm" and "9 cm" graticule lines in the procedure are intended as reminders to use this method. See Fig. 11-1

PARALLAX ELIMINATION: To eliminate effects of parallax on adjustment and measurement accuracy, either of the two methods below may be used:

Method 1: (Preferred) Place a small, unshielded light bulb above and behind you, and reduce other illumination until graticule line shadows are easily visible on the phosphor. Align time marks with the graticule line shadows.

Method 2: (Alternate) Cast sufficient illumination on your own face so that its reflection is easily visible in the graticule. When checking a given time-mark, sight with one eye, lining up the time-mark, the graticule line, and the reflection of the pupil of your eye. When the three are exactly superimposed, parallax error will be eliminated, and the time mark will be exactly aligned with the graticule line.

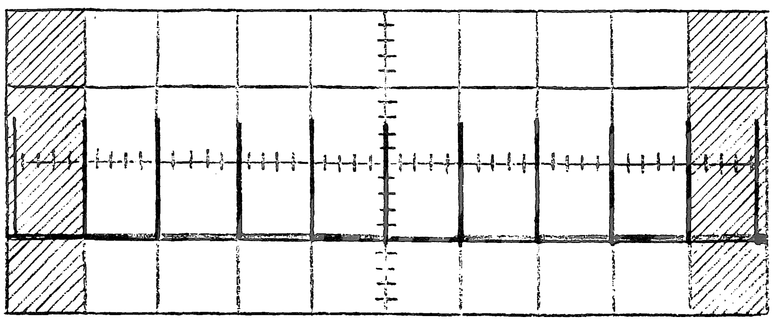


Fig. 11-1 Using middle 8 cm of sweep for most accurate timing. Linearity error is confined to outermost 2 cm (shaded area).

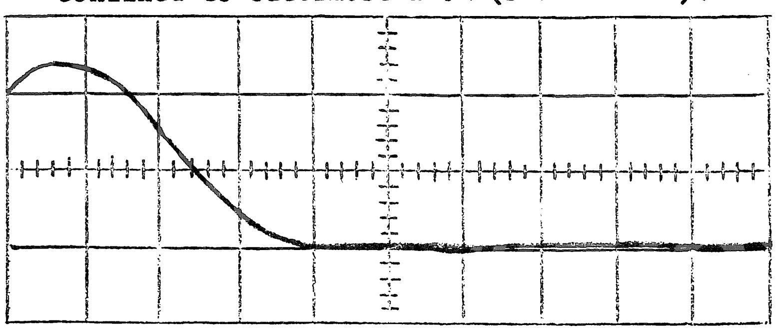


Fig. 11-2 Main Sweep Delayed display for setting Delay Start/Stop & D. S. timing.

11 SWEEP CALIBRATION. Log type and serial number of Time-Mark generator in Calibration Record.

11.1 FIRST CHECKS AND ADJUSTMENTS: Turn off Main Sweep and turn Horizontal Display switch to Delaying Sweep. Set Delaying Sweep controls as follows:

Time/Cm	500 μsec/cm
Length	Clockwise
Stability	"Triggerable"
Triggering Level	"0"
Slope (Toggle Sw)	+
Atten " "	X1

Patch from Vert Sig Out to Trig Or Ext Sweep In.

Connect Type 180 or 180A Time Mark generator Marker output to vertical input of scope, using coaxial cable. Set Time-Mark generator for 500 microsecond markers.

11.1.1 Basic Sweep Calibration

11.1.1.1 Calibration Check: Adjust Delaying Sweep Triggering Level for stable display of time-marks. Align second marker from left with 1 cm graticule line (See Fig. 11-1), and check for exact alignment of markers and graticule lines across middle 8 cm of graticule. Log any displacement of 10th marker from 9 cm graticule line in Cal Record. (1 mm = 1%; log + if to the right, - if to the left of the graticule line).

11.1.1.2 Sweep Cal Adjustment: If any timing error was indicated in 11.1.1.1, locate Sweep Cal control on bracket above main sweep deck, and adjust for exact coincidence of time marks and graticule lines across middle 8 cm of graticule. Note adjustment in Cal Record.

11.1.2 Magnifier Calibration

11.1.2.1 Calibration Check: Cancel 500 μsec markers from Time Mark generator and substitute 100 μsec markers. Turn Magnifier on, and check for exact coincidence of graticule lines with markers (reposition if necessary) over the middle 8 cm. Log any timing error over middle 8 cm in Cal Record.
Linearity: If, with perfect coincidence of the 2nd and 10th markers with the 1 cm and 9 cm graticule lines, the 6th marker falls more than 1 mm (1/2 small division) from the 5 cm graticule line, proceed as in 11.2.3 for nonlinear sweep. Check Cal Record.

11.1.2.2 Mag Gain Adj: If any timing error was indicated in 11.1.2.1, locate Mag Gain control on bracket above sweep deck. Adjust Mag Gain for exact coincidence of graticule lines with markers over the middle 8 cm. Note adjustment in Cal Record. Check linearity as in 11.1.2.1.

11.1.3 Sweep/Mag Registration: With Magnifier on as in 11.1.2 position the start of the sweep to the 5 cm (center) graticule line, exactly. Turn Magnifier off, and use Sweep/Mag Regis to position the first time-mark back to the 5 cm line. Now, using 1 millisec markers, check to see that any marker positioned to the 5 cm line with the Magnifier on is centered when the Magnifier is turned off. Log adjustment in Cal Record.

11.1.4 Sweep Amplifier Check: With the Magnifier on and sweep positioned as in 11.1.3, rap sharply on the scope with your hand, watching for horizontal microphonics. Now, turn Magnifier off and on at about 5 second intervals, watching for slow drift after switching (DC Shift). Repeat with sweep positioned far to the left. If microphonics or DC shift appear, see 11.2.5. Check Cal Record if O.K.

11.1.5 Main Sweep Timing:

11.1.5.1 Calibration Check: Turn Horizontal Display switch to Main Sweep Normal and obtain a triggered display of 1 millisec markers. Check timing over middle 8 cm as in 11.1.1.1, and log any timing error at 9 cm mark in Cal Record.

11.1.5.2 Main Sweep Vernier (R99M) Adj: With display as in 11.1.4.1, locate R99M on the Main Sweep Time/Cm Multiplier bracket.

CAUTION: The screwdriver slot in this control is at -150V. Use tool with insulated shaft for adjustment.

Adjust this control for exact Main Sweep timing over middle 8 cm of display. Note any adjustment in Cal Record.

11.1.6 Main Sweep Length: Remove vertical input and free-run Main Sweep at 1 msec/cm. Adjust Sweep Length control (on bracket above main sweep deck) for 10.5 cm sweep length. Log in Cal Record.

11.1.7 Sweep Amplifier Fast Sweep Check: Free-run Main Sweep again, with Horizontal Display Switch on Main Sweep Normal. Observe sweep length as Time/Cm is turned to 0.1 μsec/cm. If horizontal amplifier is functioning normally, sweep will lengthen appreciably to the right at the fastest sweep rates. If sweep remains at 10.5 cm length or shortens at fastest sweep rates, horizontal amplifier tubes may be too weak to permit calibration of fast sweeps or C240 and C254 are far out of adjustment. For either difficulty see 11.2.7.1.

11.1.8 Delaying Sweep Length: Turn Horizontal Display switch to Delaying Sweep and turn off Main Sweep. Free-run Delaying Sweep at 1 msec/cm. With Delaying Sweep Length control (concentric with D.S. Time/CM knob) clockwise, check for 10.2 to 10.8 cm sweep length. Log in Cal Record. Now turn Length control CCW, and check for 3.2 to 3.8 cm length. Log actual length in Cal Record.

11.1.9 Sweep Amplifier Gain: Turn Horizontal Display switch to Ext Sweep, turn Magnifier on, and turn Stability Or Ext Sweep Atten clockwise. With Atten toggle switch at X1, patch 1-volt Calibrator output to Ext Sweep In and check for two-dot display. Dots should be spaced at least 5 cm apart. Divide cm deflection into 1 and log in Cal Record (volts per cm).

11.2 PRELIMINARY TROUBLESHOOTING: It is assumed in the steps below that Calibration Steps 1 through 10 have been completed as far as possible, and that Power Supply, CRT and other circuits are functioning normally. Recheck earlier steps if in doubt.

11.2.1 No Sweep:

11.2.1.1 No Main or Delaying Sweep:

(a) See if Horizontal Position controls (5.2) are functioning normally. If not, proceed as in 11.2.3. If OK,
(b) Check Horizontal Amplifier Gain (11.1.8). If OK,
(c) Check proper operation of Horizontal Display switch and associated wiring.

11.2.1.2 No Main Sweep, Delaying Sweep OK:

(a) Connect probe from test scope to cathode, pin 8 of V58B. With Horizontal Display Switch in Main Sweep Normal, rotate main sweep Stability control back and forth through its range, but not into "preset". If repetitive 50 v gate waveform appears on test scope (run test scope at slower sweep than scope under test) the sweep generator circuits are all normal. If voltage jumps up +50 v as Stability control enters "free-run" range, but no repetitive gate is generat ed, gating multivibrator is OK, and Miller (V80, V85, V90) or holdoff(V54) circuits are at fault. If voltage simply rises proportionally to Stability position, try replacing V70. If no change in voltage, try replacing V37, V43 and/or V58.
(b) Neon Bulb B95 is normally lighted. If B96 is also lit, try replacing V85, then V90.

11.2.1.3 No Delaying Sweep, Main Sweep OK:

(a) Check as for No Main Sweep, except connect probe to cathode, pin 8, of V172B. Set Delaying Sweep to run faster than test scope. If voltage jumps +50 v with Stability rotation, trouble is in Miller circuit (V180, V190, V150). If no jump in voltage, replace V155. If no change in voltage, try replacing V140 and/or V150.

(b) Neon bulb B187 is normally lit. If B180 is also lit, replace V150 and/or V190.

(c) Check DC filament line to V190 (100 v at pin 4, 87-1/2 v at pin 3) and to V180 (87-1/2 v at pin 4, 75 v at pin 3). These filaments are in series with plug-in filament string. If voltages are off, check to see that proper tube types (12AU6, 12AL5) are in sockets; try a different plug-in.

11.2.3 Nonlinear Sweep:

11.2.3.1 Both Sweeps Nonlinear: Try interchanging V265 and V272. If this affects linearity, replace both*. If not, try replacing V240 and/or V246. Recheck 500 v and 350 v supply regulation and voltages. Check Sweep Amplifier Gain (Step 11.1.8); check for horizontal compression as 2 cm external input is positioned across graticule. If none, check out both sweep generators. Recheck HV for proper regulation and voltage.

11.2.3.2 One Sweep Nonlinear: Check for excessive signal at Miller Integrator grid. If over 500-800 mv p-p, try replacing Miller tube (V90, V190). Replace disconnect diodes (V80, V180) and/or output CF (V85, V150). Check component values, especially Miller tube plate load. (Main Sweep Only: Try removing V73, possibly shorted.) (Delaying Sweep only: See 11.2.1.3 (c), DC filament line check.)

11.2.4 Sweep Starting Point Erratic:

NOTE: A slight change in starting point is normal between Main and Delaying Sweeps. Also, at fastest Main Sweep rates, some shift of starting point to the right is normal. This should not exceed about 1 cm, however.

Check holdoff times (Step 14). See if sawtooth returns to 0 v on midrange sweeps. Try replacing disconnect diodes; check plate load resistor of -multivibrator (R69 or R164). If sawtooth waveform is normal, check gate (unblanking) waveform at cathodes (pins 3 & 8) of V840. Try new V840; check C834 (on F & I chassis) for open or intermittency.

11.2.5 Sweep Ripple or Microphonics (Horizontal Jitter); or DC Shift:

11.2.5.1 Both Sweeps: Try replacing Sweep Amplifier tubes, in this order: V240 (in shield), V246, (located just behind Horiz. Position control), V265, V272, V282.* Recheck regulated supplies for ripple, microphonics, or poor regulation.

11.2.5.2 One Sweep: Try replacing disconnect diodes; then Miller tube, then output CF.

NOTE: Sweep will show 70 kc ripple if shield is removed from HV oscillator circuit at rear of sweep deck. Keep shield in place during calibration.

*TUBE REPLACEMENT NOTE: If V246 is replaced, be sure to repeat Step 3, Calibrator adjustment. V265 and V272 should always be replaced at the same time. Use Type ECC88/6DJ8 or E88CC/6922 if possible. If not, use aged and selected 6BQ7's, Tektronix p/n 157-022. Repeat 11.1 after any tube replacement. If V265 and V272 are replaced, check linearity of magnified sweep carefully (11.1.2.1).

11.2.6 Timing Problems:

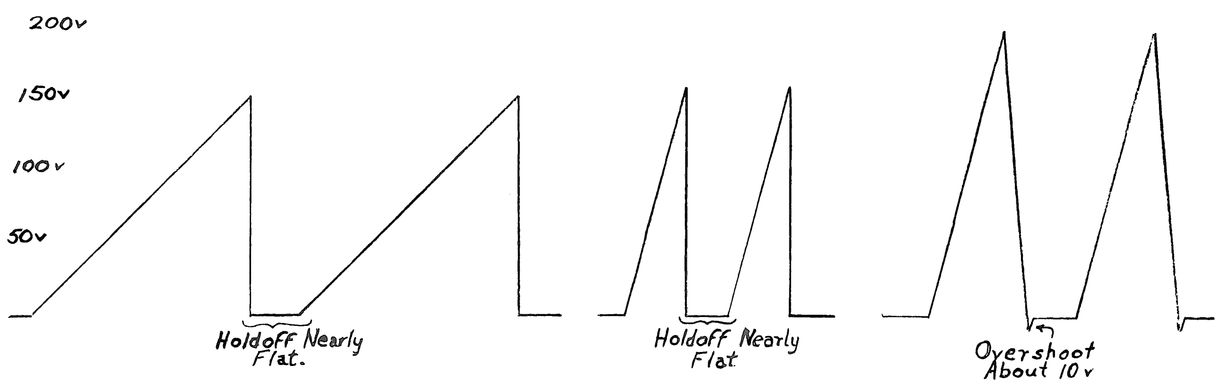
11.2.6.1 Delaying Sweep Won't Time: Try replacing V190, V180 and/or V150. Recheck -150 v supply for correct voltage. If Max Sweep Length (11.1.6) is off, recheck Horizontal Gain (11.1.8). Try setting up basic timing on 2 msec/cm (timing component check).

11.2.6.2 Main Sweep Won't Time: Try replacing Delaying Sweep tubes, as above, to isolate actual defect. Try setting up basic Sweep Cal on 2 msec/cm. Replace Main Sweep Generator tubes V90, V80, and/or V85. Check timing of other Main Sweep ranges between 100 msec/cm and 100 μsec/cm.

NOTE: Frequently, timing problems that seemingly can be traced directly to specific timing resistors are actually due to leakage or gas in sweep generator tubes. Always try tube replacement first before changing timing components.

11.2.7 Sweep Shortens at Fast Rates: If a free-running sweep fails to lengthen at faster sweep rates, try replacing V265 and V272 (see TUBE REPLACEMENT NOTE, previous page). If tube replacement does not produce an increase in fast sweep lengths, C240 and C254 are probably far out of adjustment, and will have to be preset before fast sweep timing. Replace original tubes, and proceed with 11.2.7.1.

11.2.7.1 C240, C254 preset: Free run Main Sweep at 10 μsec/cm. Check probe compensation of test scope, and set test scope to 50 μsec/cm. Use test scope and probe to observe 150 v sawtooth waveform at R.H. deflection plate of scope under test (green/white coded lead from pin 8, V272 to deflection plate).
Adjust C240 and C254 (located at the rear of the sweep chassis) for optimum square corner at the start of the holdoff portion (See Fig 11-2.7A) of the sweep waveform. Final adjustment will be made in Step 11.4.2.



A. Scope under Test, 10 μsec/cm Test Scope, 50 μsec/cm Amplitude approx 155 v

B. Scope under test, 1 μsec/cm Test scope, 50 μsec/cm. Amplitude approx 160 v

C. Scope under test, 0.1 μsec/cm. Test Scope, 5 μsec/cm. Amplitude approx 190 v

Fig. 11-2.7 FAST SWEEP WAVEFORMS

11.2.8 Delaying Sweep Length out of Tolerance: Recheck Sweep Calibration (11.1.1). If normal, R181B and R182B can be changed if desired, to restore normal range of Delaying Sweep Length control. Remove old resistors and use two resistance-substitution boxes simultaneously to select new values for these resistors. R181B usually falls between 12 and 18k; R182B between 47 and 68k.

11.2.9 Retrace Visible: Try replacing V840; check cathode resistor R840 (68k). Check fall-time of +Gate waveform. If overlong, try treplacing Sweep Gating Multivibrator tubes; check Multivibrator CF cathode resistor.

11.2.10 "Clipping" of R.H. End of Sweep: Occasionally, the positive pulse generated by the resetting of the trigger multivibrator will shorten the sweep intermittently, during triggered or "automatic" operation. This is normal if confined to the last cm or so of the sweep. A circuit modification is available if the problem is serious in your application (contact your Tektronix field engineer).

11.3 SLOW SWEEPS, MAIN SWEEP

11.3.1 Measurements: Turn Horizontal Display switch to Main Sweep Normal, Triggering Mode to AC Fast or AC Slow, and Trigger Slope to +Int. With vertical Volts/Cm set for convenient display amplitude, apply time markers from Type 180 (A) Time-Mark generator according to the table below, and adjust Stability and Triggering Level controls for a stable triggered display. Check for timing error over middle 8 cm of graticule. (See Fig. 11-1) and log error at 9 cm line in Cal Record (1mm = 1%). If error exceeds 2% at any calibrated sweep setting, follow troubleshooting procedure 11.3.2.

TIME/CM Setting	MULTIPLIER Setting	VARI-ABLE	TIME MARKERS From 180A	CORRECT DISPLAY	COMPONENT (S) Being checked
100 µsec	X 1		100 µsec	1 mark/cm	C99C & D
100 µsec	X 2		100 µsec	2 marks/cm	R99E & F
100 µsec	X 5		500 µsec	1 mark/cm	R99D
100 µsec	2.5-1	CW	100 µsec	1 mark/cm	R99L
100 µsec	2.5-1	CCW	500 µsec	5 (min) in 10 cm	R99K, R99L
100 µsec	5 - 2	CCW	500 µsec	10 (min) in 10 cm	Switch
100 µsec	12 - 5	CCW	1 msec	12 (min) in 10 cm	Switch
Check for smooth Variable action in all ranges					R99L
10 msec	X 1		10 msec	1 mark/cm	C99B
100 msec	X 1		100 msec	1 mark/cm	C99A
1 sec	X 1		1 sec	1 mark/cm*	R99C
1 sec	X 2		1 sec	2 marks/cm*	R99B
1 sec	X 5		5 sec**	1 mark/cm*	R99A

*Position base-line down off-screen to avoid burning phosphor while making measurements at the 1, 2, 5 sec/cm sweep speeds.

**If Type 180 is used, use 1 sec markers and check for 5 marks/cm.

TABLE 11-1

11.3.2 Troubleshooting:

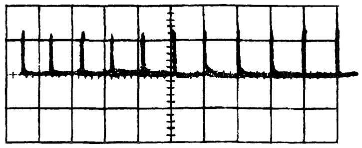
11.3.2.1 One Calibrated Sweep Off: Check value of component indicated in right-hand column.

11.3.2.2 Error Increases on Slowest Sweeps: Try replacing V90, then V80 (possible leakage or gas). Check for possible leakage across tube sockets, switch wiring, etc. 500 meg ohms leakage will throw 5 sec/cm timing off by over 10%.

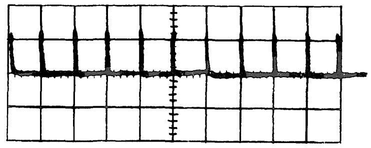
11.3.2.3 All Sweeps Checked Show Constant Error: Recheck 11.1.4. If OK, measure R99F (can be measured on switch if V90, & V80 removed) and C99C.

11.3.2.4 General: Check for correct voltages and waveforms throughout timing circuits; try removing V73; check for malfunction of V85 or neon bulb B95. Recheck Horizontal Amplifier; try Step 11.5.1 for severe waveform aberrations with both sine and square-wave displays.

11.4 FAST SWEEPS, MAIN SWEEP:



A. Second half of sweep is timed first with timing capacitor C99(-).



B. First half of sweep is then timed with Horiz. Amplifier compensation.

Fig 11-3. Showing method of timing fast sweeps (Steps 11.4.2.1 through 11.4.2.4) for correct linearity.

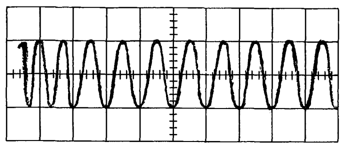


Fig 11-4 Normal compression of first 60 nsec of .02 μsec/cm sweep (.1 μsec, Mag on).

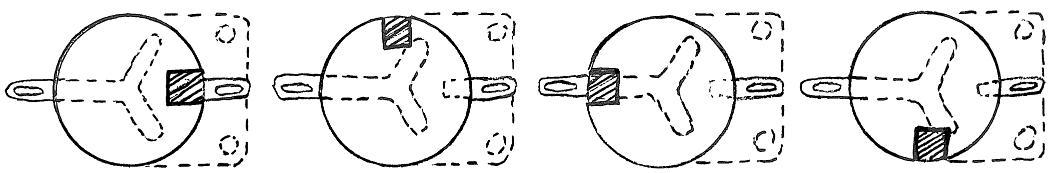


Fig. 11-5 Showing physical configuration of capacitors C278 and C286. When notch on rotor is directly above I-shaped terminal, capacitance is maximum. When notch is over Y-shaped terminal, capacitance is minimum. Check actual capacitor orientation in scope under test. Normally, orientation of both C278 and C286 is as shown. The two capacitances should always be approximately equal. In most instruments, capacitors are equipped with bakelite backing plates, shown above in dotted lines, making electrical orientation visible from above.

11.4 FAST SWEEPS, MAIN SWEEP: (Use Type (53/54) K or L Plug-in)

11.4.1 Measurements: Set up front-panel controls as in 11.3.1, but set Trigger Slope to +Ext and patch from Type 180 (A) Trigger Output connector to scope Trigger Input. Set 180A for 100 kc triggers, or 180 for 10 kc triggers. Measure timing error over middle 8 cm for each sweep rate in chart below, and log in Cal Record under "Initial".

NOTE: In making .02 µsec/cm (.1 µsec, Mag On) measurements, the three cycles of 50 mc sine waves at the very start of the sweep are normally "jammed up" (60 nsec nonlinearity). However, since the first five cycles actually occur before arrival of the trigger (delay-line action), linearity here is not critical. Position the first three or five cycles (see chart) off to the left for measurements.

TIME/CM Setting	MULT.	MAG.	TIME-MARKS From 180 (A)	POSITION	DISPLAY	SPEC
10 µsec	X 1	Off	10 µsec	2nd mark at 1 cm line	1 mark/cm	1%
1 µsec	X 1	Off	1 µsec	" " " " " "	1 mark/cm	1%
1 µsec	X 2	Off	1 µsec	3rd " " " " "	2 marks/cm	2%
1 µsec	X 5	Off	5 µsec	2nd " " " " "	1 mark/cm	2%
.1 µsec	X 1	Off	10 mc sine*	" " " " " "	1 cycle/cm	1%
.1 µsec	X 1	On	50 mc sine*	Center, as above	1 cycle/cm	2%
.1 µsec	X 1	On	50 mc sine*	Start, skip 3 cycles	1 cycle/cm	2%
.1 µsec	X 1	On	50 mc sine*	Start, skip 5 cycles	1 cycle/cm	2%
.1 µsec	X.1	On	50 mc sine*	End (Hor. Pos. CCW)	1 cycle/cm	2%

*For greatest accuracy, center display vertically; use point at which sine-wave crosses centerline for measurement. Use 2 cm display.

TABLE 11-2

11.4.2 Adjustments: If measurements in 11.4.1 do not fall within specified tolerances, proceed as outlined below. Unless only minor touch-up is required, complete all steps below.

11.4.2.1 10 µsec/cm: Apply 10 µsec marks as in 11.4.1. Align the 11th marker with the right-hand edge of the graticule (10 cm line). Adjust C99F (upper trimmer of three on Time/Cm switch) with non-capacitive tool for alignment of the last five markers with graticule lines. Then adjust C240 (above V240 at rear of sweep deck) for alignment of first-half markers (starting with second marker) with graticule lines. Now, touch up C99F, then C240 again for perfect timing over middle eight cm.

11.4.2.2 1 µsec/cm: Display 1 µsec marks at 1 µsec/cm. Adjust C99H (on time/cm switch) for timing of second half of of sweep as in 11.4.2.1; then C254 for correction of first-half timing. Touch up C99H, then C254 for perfect timing in middle 8 cm. (C254 is located near C240 at rear of sweep deck).

11.4.2.3 .1 μsec/cm: Display 10 mc sine waves from Time-Mark generator. Increase deflection if necessary, for 4 cm display. Adjust C99J (lowest of three on Time/Cm switch) for timing of last half of sweep; adjust compression trimmer C267 (on Mag Gain pot terminals) for timing of first half of sweep. Touch up C99J, then C267 for correct timing over middle 8 cm.

11.4.2.4 .02 μsec/cm: At .1 μsec/cm, Magnifier on, apply 2 cm (more will overload vertical amplifer) of 50 mc sine waves from Type 180(A). Locate the two "bootstrap" capacitors C278 and C286 on the horizontal output ceramic strip. These should have approximately equal capacitance settings. See Fig. 11-5. Center the display with Mag off, then switch Mag on. Timing at this (center) part of sweep should be very close. If not, re-check Mag Gain (Step 11.1.2.2) and 11.4.2.1-2-3 before proceeding further.

Now, turn to the start of the sweep (position controls CW), and position the first 5 cycles off to the left. Check timing. Make small equal adjustments in C278 and C286 to correct any error. Recheck center and end of 50-cm sweep for correct timing ±2%. If necessary, repeat steps 11.4.2.1-2-3 again to improve linearity. Final adjustment should bring .02 μsec/cm sweep within 2% for all except first 3 cycles, although 5 cycles of non-linearity can be tolerated. If repetition of these steps will not bring .02 μsec/cm sweep within tolerance, follow troubleshooting procedure.

11.4.3 Final Checkout: Proceed as in 11.4.1.1, logging sweep timing errors in "Final" column in Cal Record.

11.4.4 Troubleshooting: If sweeps show considerable non-linearity at right-hand end, trouble is probably in V265 and V272. Replace. If adjustments indicated will not bring in timing at left-hand end, try replacing V282 as well, and V240. Remember that V265 and V272 must be replaced by either Type ECC88/6DJ8 (or E88CC/6922) or aged and checked Type 6BQ7A, p/n 157-022. Some selection of ECC88's may be necessary for optimum linearity. If any tubes are replaced repeat Step 11 in its entirety. If tube replacement does not work, check components, starting with "graham-cracker" resistors R278 and R286. If V246 is replaced for any reason, repeat Step 3.

11.5 HORIZONTAL AMPLIFIER INPUT COMPENSATION:

11.5.1 Compensation Check: Set front-panel controls as follows:

Control	Setting	Control	Setting
Stability	"Triggerable"	Triggering Mode	AC Slow
Triggering Level	About 1/8" CW from 0.	Trigger Slope	+ Ext
Time/Cm	10 μsec/cm	Hor. Display	M.S. Normal
Multiplier	X 5	Atten (toggle)	X 1
Magnifier	ON	Slope (toggle)	+
Volts/Cm	20	Ext Swp Atten	Clockwise

Terminate Type 105 Square Wave Generator in 93 Ω at output connector with B93R terminator. Attach 93 Ω cable and terminate cable with another B93R terminator. Attach coaxial "Tee" to terminator and to Ext Sweep Input of scope. Patch from the free arm of the Tee to the Trigger Input. Set vertical Volts/Cm to 20 and Variable CCW. Patch from vertical input to Sawtooth Output connector. Set Type 105 for 2kc repetition rate and apply DC power. Adjust output amplitude for about 5 cm horizontal deflection on scope. Adjust sweep and vertical controls of scope so that vertical-sweep display contains about 2 cycles of square-wave. Important: Replace cabinet on scope for this measurement.

Examine left-going (positive) side of waveform for overshoot. The value here will be "normal" up to 1 or 2 mm, due to amplifier compensation for optimum sawtooth reproduction. Now, remove Tee connector and install 47 μμf input capacitance standardizer (CS47) between Tee and Ext Sweep Input. Increase 105 output and compare the waveform with that obtained before (C110 check). Now switch Atten toggle switch to X 10, increase amplitude again, and compare waveform against first waveform obtained. (C100, C101 check). If all waveforms were substantially identical, check Cal Record. If not, proceed with 11.5.2.

11.5.2 Adjustment: Capacitor C110 standardizes the input capacitance at Ext Sweep Input at 47 μμf in the X 1 Atten position. C100 and C101 re-standardize the capacitance and compensate the attenuator in the X 10 position. With the CS47 standardizer still in place, first adjust C110 for closest reproduction of the original waveform obtained in 11.5.1 without the standardizer, Atten X 1. Then, with Atten X 10, adjust C100 and C101 (different time-constants) for optimum reproduction of the original display. These capacitors should be adjusted with the fingers, to simulate cabinet capacitance, and the final adjustments double-checked with the cabinet in place. Log correct adjustment of these capacitors in the Cal Record.

NOTE: Do not attempt to correct for the overshoot or wrinkles on the negative (right hand portion) of the Type 105 waveform display. This is most likely caused by cathode interface in the 105 output tubes, and not by the scope under test.

12 DELAY AND LOCKOUT SYSTEM.

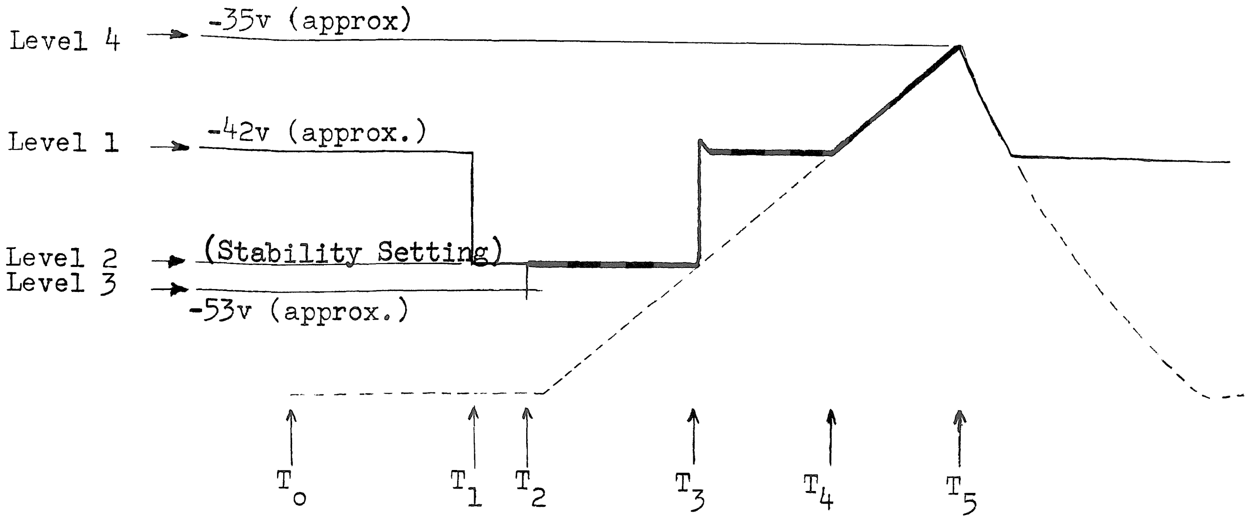


FIGURE 12-1 Complete Lockout Cycle. Solid line: Waveform at grid of V58A; also at cathodes of V37B, V43A and V54A. Dotted line: Waveform at grid of V54A.

Voltage Levels:

1. Quiescent level of Trigger Gate Generator cathodes. "Lockout Level" -- sweep cannot run.
2. Trigger Gate Level, controlled by Stability control setting. Waveform drops to this level when Trigger Gate Generator is flipped by Delayed Trigger or Reset pulse. Shown, "Triggerable".
3. Sweep-Start Level. Level at which Sweep-Gating multivibrator flips to start sweep generator. Shown being penetrated by trigger from V20, at T2. Further clockwise setting of Stability control would penetrate this level at T_1, causing Main Sweep to run immediately after Delayed Trigger.
4. Sweep-Stop Level: Level at which Sweep-Gating multivibrator (V58, V70) reverts, stopping sweep.

Time-Sequence:

T0 Start of Delaying Sweep.
T1 Expiration of delay period. Delayed Trigger trips Trigger Gate generator, arms Main Sweep by opening trigger-gate.
T2 Trigger from V20 trips Sweep Gating multivibrator, Sweep Generator starts.
T3 V54A comes out of cutoff momentarily, reverts Trigger Gate generator.
T4 V54A, still driven by sawtooth, comes out of cutoff again, controls V58A grid level.
T5 Sawtooth from V54A reaches Sweep-Stop level, flips sweep-gating multivibrator, stops sweep.

NOTE: During adjustment of R64 (Step 12.2), Stability Setting (Level 2) is set slightly below Level 3, and R64 is adjusted for proper proportions between Levels 1-3 and 1-4 to insure complete lockout.

12.1 DELAYED TRIGGER.

12.1.1 Check: Turn Horizontal Display Switch to Main Sweep Normal and free-run Main Sweep at 10 μsec/cm. With Delay Time Multiplier set to 2.00, patch from Del'd Trig connector to vertical input, setting Volts/Cm to 5. Check for 5v minimum trigger, positive-going. Position baseline of display below visible scan area, so that only top of trigger waveform is visible. Step Main Sweep Time/Cm switch through all ranges from 1 sec/cm, to 1 μsec/cm, changing intensity as required to check trigger amplitude (it may be necessary to use viewing hood at slowest sweeps). Log smallest amplitude noted, in Cal Record.

Now, turn Horizontal Display to Main Sweep Delayed, and free-run Delaying Sweep. Set Main Sweep Time/Cm to 5 μsec/cm. Peak of Delayed Trigger should be visible at start of trace. Step Delaying Sweep throughout its ranges and log minimum Delayed Trigger amplitude in Cal Record. If less than 5v at any range, follow 12.1.2 Troubleshooting procedure.

12.1.2 Troubleshooting:

12.1.2.1 No Delayed Trigger: Try replacing Delay Pickoff tubes (on swingout chassis) V216 (6U8), V228 (6U8), V195 and 196 (usually 6AU6's). Check for possible open or short in R209 (helipot), R208 (Delay Stop) or R195 (Delay Start). With test scope, check waveforms. Plate of V216B should show switching waveform: grid of V228B should show 10v minimum spike and -5v bias.

12.1.2.2 Delayed Trigger Too Small: Replace V216 (6U8). Try replacing V228 (6U8). Check for -5v bias and +10v spike at grid of V228B. Check components associated with V216, starting with R224. If bias and spike at V228B grid are normal, check R231.

12.1.2.3 Delayed Trigger OK, but No "Main Sweep Delayed": Replace V37 (6U8) and/or V43 (6U8), on the Main Sweep deck. Check for presence of Delayed Trigger at grid, pin 2, of V37A, and of plate voltage at pins 6 of both V37 and V43 in Main Sweep Delayed and Delaying Sweep positions of Horizontal Display switch. Check Trigger Gate generator components; try replacing V54, V58, or V70. Try experimental settings of R64.

12.2 LOCKOUT LEVEL:

12.2.1 Check: Remove patch set up in 12.1, set vertical Volts/Cm to .5 and attach 10X probe. Check probe compensation, then use hook or pincer tip to attach to grid end (away from switch) of C58, the 27pf capacitor from the Trigger Slope/Mode switch to V58 pin 2. Turn Horizontal Display Switch to Delaying Sweep, and turn both Stability and Triggering Level controls CW. Turn Triggering Mode to "AC Slow". With Main Sweep Time/Cm on 2 msec/cm, and Delaying Sweep at 5 msec/cm, set Delay Time Multiplier to about 3.00. A display similar to Fig. 12-2 below should appear. Back off Main Sweep Stability until the Main Sweep just free-runs. Measure amplitude of the trigger gate and sawtooth portions of the waveform. The trigger gate should be 9-11 volts; the sawtooth portion 2/3 of this voltage. If these amplitudes and proportions are correct, check Cal Record and proceed with 12.3. If not, complete 12.2.2.

12.2.2 Lockout Level Adjust (R64): If waveform voltages and/or proportions are not as specified in 12.2.1, locate R64, the miniature control mounted on the ceramic strip above V58. Keeping Stability just on the edge of free-running (this will require continual readjustment), make small adjustments in R64 until displayed waveform falls within specifications. When final R64 setting is reached, repeat Step 9.2.3.5, Preset Stability adjustment. Note in Cal Record.

12.2.3 Troubleshooting: The procedure above assumes completion of all previous calibration steps, especially 12.1 and 11.1.5 (Sweep Length). Circuits contributing toV58A grid waveform are Trigger-Gate Gen (V37, V43), Holdoff (V54), and Trigger (V20). Trigger circuit should be disabled (Triggering Level) for these checks. Try tube replacements first, starting with V37 and V43, then V54, V58 and V70; then check associated components, particularly R50 and R51 (grid, V37B) R48, R65, and R66. Repeat 12.2.2 after tube replacement. See also troubleshooting notes in Step 12.1.2.

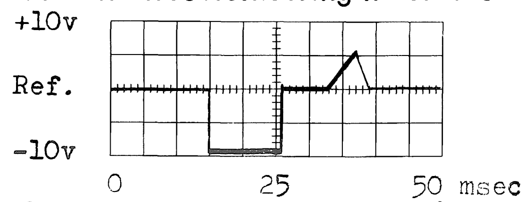


FIGURE 12-2. Typical waveform obtained in 12.2.1. Since reference DC level is usually about -42v, AC coupling is used, if Type Z plug-in is unavailable. Waveform illustrated shows 9v trigger-gate and 6 v sawtooth amplitude. Display should be intensified as shown from the start of the trigger-gate to the top of the sawtooth. See instruction manual and Fig 12-1 for further information.

12.3 SINGLE SWEEP CHECK:

12.3.1 Manual Sweep: Remove probe from C58, set Calibrator for 10v output, and attach probe to Cal Out connector. Turn Delaying Sweep Generator off and Horizontal Display to Main Sweep Delayed. With Main Sweep Stability full clockwise, press Reset button several times. One sweep should be generated each time. Check Cal Record.

12.3.2 Triggered Single Sweep: Remove probe from Cal Out, turn Stability control to "Preset" or "Triggerable" range and Triggering Level to "O", with +Int and AC Slow Slope and Mode settings. Press Reset button. "Ready" light should come on, but no sweep should be generated. Now, touch probe to Cal Out connector. A single sweep should be generated, and the "Ready" light should go out. Repeat several times, making sure that circuit is working properly, at several Time/Cm settings. Note proper operation in Cal Record.

12.3.3 Troubleshooting: Defective operation in the "Single Sweep" mode will most likely be caused by a defective Reset switch or associated components (C235, C236, R235, R236 or R231) or by Trigger Gate Generator malfunction. Check for 5v minimum trigger at Del'd Trig connector when Reset button is pushed. If OK, repeat steps 12.1 and 12.2, replacing tubes as required.

12.3.4 Rate Generator Action (Final Checkout). Set up as for 12.3.2, but trigger Delaying Sweep from Vert Sig Out connector, and with Slope toggle switch on "-". Set Main Sweep Time/Cm to 100 μsec/cm, and connect probe tip to Cal Out connector for 2 cm display of 1 cycle of Cal waveform. Use test scope to observe several cycles of Sawtooth Output waveform, as delaying Sweep Time/Cm is stepped through its range. Delaying Sweep Time/Cm and Length controls should control Main Sweep repetition rate up to about 50 μsec/cm Time/Cm setting of Delaying Sweep; above this, the Delaying Sweep Time/Cm or Length should not affect Main Sweep rep-rate. Note proper operation in Cal Record.

NOTE: Exact rep-rate of Main Sweep in this mode is always some sub-multiple of Calibrator frequency, so Length control will appear to change rep-rate in fixed increments, at faster Time/Cm settings.

12.4 PICKOFF DRIFT:

12.4.1 Check: Set front panel controls as follows:

Horizontal Display	Main Sweep Delayed
Main Sweep Stability	Clockwise
Trigger Mode	AC Slow
Time/Cm	.5 µsec/cm
Magnifier	Off
Time/Cm or Delay Time	500 µsec/cm
Delay Time Multiplier	5.00
Slope (Toggle Switch)	+ (Important)

Apply 5 µsec markers fromTime Mark generator to vertical input. Trigger Delaying Sweep from Vert Sig Out and adjust Delay Time Multiplier to position a marker to the center of the graticule. Turn Atten toggle switch to X10 to stop Delaying Sweep. After 5-10 seconds, turn Atten to X1 and check for drift of the pulse display. If 5-second drift exceeds 3 mm, replace V195 and V196. If drift persists, replace V228 and/or V216. Recheck at 1.00 and 9.00 Delay Time Multiplier settings. Log final maximum drift (if any) in Cal Record.

12.4.2 Troubleshooting: If tube changes in 12.4.1 do not correct drift, replace Delaying Sweep trigger tubes (V113, V120, and/or V130) and repeat Step 10. Check +225 v power supply for drift or excessive ripple. Try replacing Delay Start or Delay Stop pots; check for poor wiper contact in Delay Time Multiplier Helipot. For jitter, see 13.4.

12.5 DELAY START/STOP:

12.5.1 Check: With front panel controls set as for 12.4, apply 500 µsec markers from 180A. Turn Horizontal Display switch to Delaying Sweep, and adjust Delay Time Multiplier so that the second marker (the one at the 1 cm line) is brightened. Turn to Main Sweep Delayed, and adjust Delaying Sweep Triggering Level and Stability controls for most stable, jitter-free display. Now, adjust Delay Time Multiplier slightly so that the pulse is positioned to the left side of the graticule (see Fig. 11-2). Log Delay Time Multiplier setting in Cal Record. Now, return to Delaying Sweep display, and set Delay Time Multiplier to brighten the 9 cm marker. Turn to Main Sweep Delayed and readjust Delay Time Multiplier to position the 9 cm marker again to the start of the delayed trace, as in Fig. 11.2. Log dial reading in Cal Record.

If either reading is off by more than two small dial divisions (0.2%) from 1.00 or 9.00, complete 12.5.2. Otherwise, proceed with 12.5.3 (Linearity Check).

12.5.2 Adjustment: Locate Delay Start Adj and Delay Stop Adj controls on swingout chassis. With Delaying Sweep display as in 12.51, set Delay Time Multiplier to 1.00, and use Delay Start Adj control to position the brightened portion of the display to include 1 cm marker* Now, turn Delay Time Multiplier to 9.00 and use Delay Stop Adj control to position brightened portion of the sweep to include 9 cm marker. Repeat these adjustments until interactions are eliminated. Now, switch to Main Sweep Delayed, and touch up both adjustments for displays similar to Fig. 11-2 at both 1.00 and 9.00 multiplier settings.

*NOTE: In some cases, it may be desirable to rough-in adjustments with Main Sweep operating at 5 µsec/cm, positioning the start (left side) of the brightened portion to the marker.

12.5.3 Linearity Check: Using Main Sweep Delayed display, log dial settings required to position each of the middle 9 markers as in Fig. 11-2. Maximum linearity error should not exceed 2 small dial divisions (.02).

12.5.4 Troubleshooting:

12.5.4.1 Excessive Linearity Error: Try replacing V190, V150 and/or V180; then try V195 and 196 (If Delaying Sweep Generator tubes are replaced, repeat Step 11. If pickoff tubes are replaced, recheck earlier steps in 12.) Try new Helipot (R209) if tube replacement does not improve linearity.

12.5.4.2 Excessive Jitter: See 13.4

13 DELAYING SWEEP CALIBRATION.

13.1 SLOW SWEEPS:

13.1.1 Checkout: Set up triggering of Delaying Sweep as in 12.5. Apply Time Marks from Type 180 (A) as indicated in table, and with Main Sweep Time/Cm settings as in table, log Delay Time Multiplier setting required to display 9 cm marker as in Fig. 11-2 for each Delaying Sweep Time/Cm setting in the table. Maximum error allowed, 1/2% (.05 on Helipot dial).

Delaying Sweep Time/Cm	Markers	Main Sweep Time/Cm	(1) Rough Check	(2) Final Check
200 μsec/cm	100 μsec	2 μsec/cm	Delaying Sweep	Main Sweep Del'd
500 μsec/cm	500 μsec	5 μsec/cm	Delaying Sweep	Main Sweep Del'd
1 msec/cm	1 msec	10 μsec/cm	Delaying Sweep	Main Sweep Del'd
2 msec/cm	1 msec	20 μsec/cm	Delaying Sweep	Main Sweep Del'd
5 msec/cm	5 msec	50 μsec/cm	Delaying Sweep	Main Sweep Del'd
10 msec/cm	10 msec	100 μsec/cm	Delaying Sweep	Main Sweep Del'd

13.1.2 Troubleshooting: If sweep accuracy does not fall within specification on any range, try replacing V190, V180, and/or V150. If tube replacement does not work, timing components will probably have to be replaced. (NOTE: Although Resistors R190A, B, C are made up of 1% and 10% components, they are matched for 1/4% tolerance. Be extremely careful in soldering not to overheat these units.)

13.2 FAST SWEEPS:

The technique for calibrating the faster ranges of the delaying sweeps basically the same as for the slow sweeps, except that allowance has to be made for fixed delay error caused by time lag between trigger-arrival and sweep generation.

13.2.1 50 μsec/cm Range: Apply 50 μsec markers from 180 (A), with front panel settings as in 13.1, set Main Sweep Time/Cm to .5 μsec/cm, and Horizontal Display to Delaying Sweep. Brighten the 1 cm marker, using the Delay Time Multiplier, then turn to Main Sweep Delayed and log dial setting required to position 1 cm marker to start of Main Sweep Delayed trace. Repeat for 9 cm marker, logging dial reading under "Initial" in Cal Record. If difference between 1 cm and 9 cm dial readings is not 8.00 ± 0.02, locate C190D on bracket adjacent to Time/Cm or Delay Time switch and adjust for correct timing. Log final 9 cm dial reading in Cal Record.

Now, recheck dial reading for 1 cm marker, and correct Cal Record if necessary.

Check 100 μsec/cm range, using 100 μsec markers, and 20 μsec/cm range, using 10 μsec markers, by the same method, logging both 1cm and 9 cm dial readings. Maximum error allowed, 5 small dial divisions (0.5%), i.e., difference between 1 cm and 9 cm dial readings must be 8.00 ± 0.05.

13.2.2 5 μsec/cm Range: Turn Main Sweep Time/Cm to .1 μsec/cm and Delaying Sweep to 5 μsec/cm. Apply 5 μsec markers, and proceed as in 13.2.1. Adjust C190F if necessary to correct timing.

If 5 μsec/cm timing is adjusted, re-check 1 cm marker, and log new dial reading, if different.

Now, use 10 μsec markers to check 10 μsec/cm timing, and 1 μsec markers for 2 μsec/cm timing, as before.

NOTE: Maximum error at 1 cm due to sweep-start delay must not exceed 12 small dial divisions at any sweep rate when Delaying Sweep Triggering Level and Stability are at optimum settings. However, this figure is approached at 2 μsec/cm normally.

13.2.2 5 μsec/cm Range: (Continued)

Log 1cm and 9 cm dial readings for 10 μsec/cm and 2 μsec/cm sweeps. Difference between readings, as before, must be 8.00 ± 0.05, for each sweep rate.

13.2.3 Troubleshooting:

13.2.3.1 Excessive Timing Error: Examine Delaying Sweep display closely, and see if direct display error corresponds to error indicated by Helidial. If not, try replacing Delay Pickoff tubes, starting with V195, V196 and V228. If error is confirmed, try tube replacement in Delaying Sweep generator, starting with V190, V150, and V180. Timing components are probably OK, unless 50 μsec or 5 μsec/cm sweeps cannot be brought in with C190D and C190F respectively.

13.2.3.2 Excessive Sweep-Start Delay: Sweep-start delay involves Delay Pickoff, Trigger-Gate and Main Sweep Gating Multivibrator circuits as well as Delaying Sweep Trigger and Sweep circuits. It is only partially compensated for in the Main Sweep Delayed mode by the vertical amplifier delay system. Try changing oldest tubes in these circuits first. If trigger-pickoff system in vertical amplifier is suspect, try triggering Delaying Sweep externally directly from 180 (A). Recalibrate sections affected by tube changes before proceeding. Failure of C197 (in V195 grid divider circuit) will cause both non-linearity of fast sweeps and excessive "sweep start delay". Failure of compensating capacitor in any multivibrator grid divider circuit will slow down action and add to delay.

13.3 LINEARITY CHECK: Check linearity at 50 μsec/cm and 5 μsec/cm as in 12.5.3. Maximum linearity error, 2 small divisions on Helidial (.02). Log maximum error, and point at which it occurs for each Sweep rate in Cal Record.

13.3.1 Troubleshooting: Linearity problems may be caused in either sweep generator or delay pickoff circuits. Try replacing V190, V150 or V180 in generator; V195, V196 or V228 in pickoff circuit first. Check C197 (to grid of V195) and C187 (to grid circuit, V150B) for possible open.

13.4 JITTER CHECK: Set up as for Pickoff Drift (Step 12.4.1), with Main Sweep Time/Cm 1000 times faster than Delaying Sweep. Adjust Delaying Sweep Stability and Triggering Level controls for minimum jitter of Main Sweep Delayed display. Jitter at 1.00 cm delay should not exceed 2 mm; at 9.00 cm, 4 mm. Log actual jitter if within spec. Otherwise, proceed with 13.4.1.

13.4.1 Troubleshooting: Try replacing Main Sweep and Delaying Sweep Holdoff tubes (V54, V150, V140); re-check for excessive power-supply ripple. Try replacement of Delay Pickoff tubes. Repeat calibration sections involving any tubes replaced. If tube replacement fails to correct jitter, check R195, R208 and R209 for excessive noise; try replacing V37, V43, V190, V180, V155, and/or Delaying Sweep trigger tubes.

14 HOLDOFF SYSTEM.

14.1 MAIN SWEEP: Free-run Main Sweep. Attach probe from test scope to + Gate, Main Sweep connector. Set test scope to trigger on "-slope". Check holdoff time (time between positive-going Gate waveforms) against table below for each Time/Cm setting, and log actual values in Cal Record. Be sure probe is properly compensated.

TIme/Cm	Holdoff	Components
1 sec/cm to 100 msec/cm	200 msec approx.	R57, C54A
10 msec/cm	20 msec approx.	C54B
1 msec/cm	2 msec approx.	C54C
100 µsec/cm	250 µsec approx.	C54D
10-1 µsec/cm	25 µsec ± 20%	R55A, C56
.1 µsec/cm	5 µsec min	R55B

14.2 DELAYING SWEEP: Free-run Delaying sweep, connect test scope probe to + Gate, Del'g Swp connector. Check holdoff times against table below, log in Cal Record if within spec.

Time/Cm	Holdoff	Components
2, 5, 10 msec/cm	10 msec, approx.	R150, C148A
200, 500, 1000 µsec/cm	1 msec, approx.	C148B
20, 50, 100 µsec/cm	100 µsec, approx.	C148C
2, 5, 10 µsec/cm	10 µsec, approx.	C148D

14.3 TROUBLESHOOTING: If holdoff times for faster ranges appear too short, compare with indicated holdoff times on sawtooth waveform (cathode followers feeding front panel connectors may be weak). For Main Sweep, measure at cathodes of V85. For Delaying Sweep, measure at cathode, pin 8, of V150B. If actual holdoff times for specific ranges are not reasonably close to indicated values, try replacing components indicated in right-hand columns above. If all holdoff times seem long or erratic, replace holdoff tubes V54 or V150, check cathode resistors, and in Delaying Sweep; also try replacing V140.

15 VERTICAL AMPLIFIER AND DELAY LINE COMPENSATION.

15.1 INITIAL PERFORMANCE CHECK: Install Type (53/54) P plug-in and preset front-panel controls as follows:

Stability	Triggerable	Horizontal Display	Main Swp. Norm.
Triggering Level	0	Trigger Slope	+Int
Time/Cm	.1 µsec	Triggering Mode	AC Fast
Multiplier	2	Coil Current	On
Magnifier	Off	Amplitude	3 O'clock

Install viewing hood. Adjust Triggering Level control for stable display with trigger-point about 1/2 cm ahead of rising portion of waveform (See Fig. 15-1). Adjust Amplitude control for about 3 cm display, and position leading edge near center of graticule.

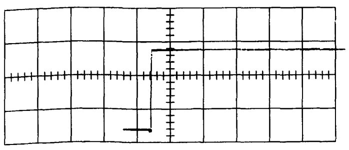


Fig 15-1 Normal P-Unit display, 0.2 µsec/cm

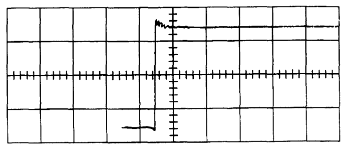


Fig 15-2 Overshoot & Ringing, 0.2 µsec/cm

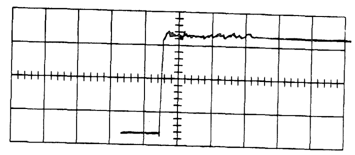


Fig 15-3 Miscellaneous "wrinkles"-0.2 µsec/cm

15.1.1 Tube Re-check: Examine waveform carefully for cathode-interface or other tube defects causing variations in transient response with 105-125 v line voltage variations, as in Step 7.1.3 (See figures 7-3, 7-4, 7-5). If tube replacement is necessary, repeat Step 7. Return line voltage to 117 v. Check Cal Record.

15.1.2 Waveform Check: Wrinkles, bumps, dips, or overshoot in the display, not affected by line voltage changes will require delay line and/or high frequency compensation adjustments. If the waveform appears as in Figure 15-1, proceed with risetime and bandwidth measurements. If aberrations in excess of a trace-width appear (Figs 15-2, 15-3) complete the adjustment procedure 15.5 before continuing.

NOTE: Overshoot not exceeding one trace-width may be allowable in some instruments if necessary to preserve risetime.

15.2 RISETIME MEASUREMENT (P-Unit): Log serial number of Type P Unit used, in Cal Record. With front panel controls set as in 15.1, proceed as follows to measure the oscilloscope risetime*.

A. Increase Main Sweep Time/Cm to .1 μsec/cm.
B. Turn Magnifier On. (For .02 μsec/cm display).
C. Turn Stability control full right, Triggering Mode to HF SYNC.
D. Adjust display amplitude to exactly 4 cm.
E. Position the (two lines) display downward exactly 4 mm, so that top line of display is exactly 4 mm below top line of graticule.
F. Turn Stability back to triggerable range, and Triggering Mode to AC FAST. Adjust Triggering Level so leading edge of display is at least 2 1/2 cm from the start of the sweep.
G. DO NOT TOUCH VERTICAL POSITION CONTROL. Adjust Horizontal position controls so the waveform display crosses the vertical centerline of the graticule exactly 8 mm below the top graticule line (See Fig. 15-5).
H. Now, measure the horizontal distance between the vertical centerline and the point at which the display crosses the bottom line of the graticule. This is the standardized risetime, and should be .012 μsec (6 mm), or just slightly less.
   If the indicated risetime is .012 μsec, and there are no aberrations in the display (Step 15.1), proceed with 15.3, after entering risetime value in Cal Record.
   If indicated risetime is greater than .012 μsec, proceed now with adjustments (Step 15.5).

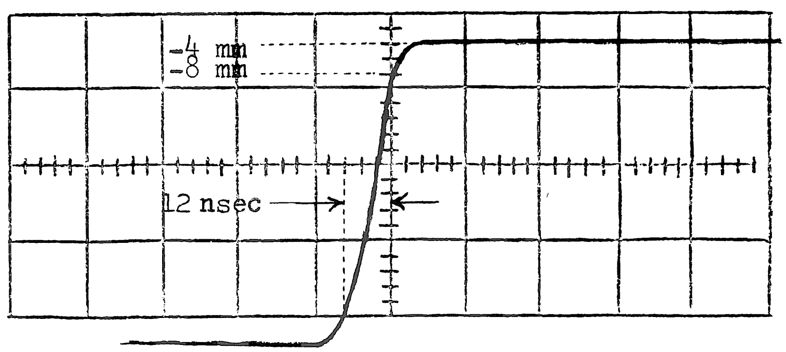


FIG. 15-5. Illustrating risetime measurement technique using standard graticule (15.2, 15.3).

*The "risetime" measured here is the response of the main-unit amplifier to the approximately 4 nsec (.004 μsec) risetime pulse from the Type P plug-in, and so should not be expected to achieve 10 nsec (.010 μsec). The theoretical figure is about 11 nsec (.011 μsec). The figure 12 nsec (.012 μsec) is used here, however, to reduce the possibility of overcompensation when using the Type P. The more important consideration is meeting the 12 nsec specification with the Type K or L plug-in. See also discussion under 15.5.2.4-D (page 3-71).

15.3 RISETIME MEASUREMENT (107): Remove P-Unit, install Type K or Type L plug-in. Turn Volts/Cm to .05, DC coupled, with Variable full clockwise. Attach Type B52R terminating resistor to vertical input. Connect 42" length of 52-Ω coaxial cable to the free end of the terminating resistor and to the output connector of the Type 107 Square-Wave generator.

Adjust output of Type 107 for 4 cm deflection. Proceed as in 15.2 to make risetime measurement by positioning display 4 mm downward, then horizontally positioning triggered display to cross vertical centerline 8 mm from the top.

If indicated risetime is now .012 μsec, log in Cal Record, along with serial number of K or L plug-in used.

If indicated risetime is greater than .012 μsec (assuming that exactly 12 nsec reading was obtained in 15.2), tag plug-in for recalibration, and select another of the same type, repeating 15.3.

The purpose of this check is to determine if plug-in aberrations will affect bandpass measurement (15.4). If any spiking or other defect is noted in K (L) display, that is not evident in the P-Unit display, recalibrate plug-in before proceeding.

15.4 BANDWIDTH MEASUREMENT: Remove cable from Type 107 and from B52R terminating resistor. Attach 10-1 T-Pad (B52T10) to terminating resistor, and connect attenuator head from Type 190A Constant-Amplitude Sine-Wave Generator to the T-Pad. Adjust the output of the 190A for exactly 4 cm deflection on the oscilloscope, using 50KC output (free-run the oscilloscope sweep).

Now, increase frequency of 190A to 30 mc. There should be at least 2.8 cm vertical deflection (3 db down). If so, this confirms your risetime measurements. Log exact -3db point and also exact value of deflection at 30 mc in Cal Record, along with serial number of 190A.

If -3db point did not fall at 30 mc, re-check risetime measurement with both P-Unit and with Type K or L plug-in. Proceed with adjustments (15.5) as necessary to obtain proper risetime and bandwidth with minimum display aberrations.

NOTE: The specifications for some instruments called for deflection at 30 mc to be "-3db ± 1/2db". This puts the limits for vertical deflection at 30 mc (with 4 cm display at 50 kc) at 2.7 and 3.0 for these instruments, rather than at 2.8 cm. These limits should be rigidly observed, as departures in either direction are likely to be accompanied by excessive spiking or rounding of the "corners" of a step-function.

CAUTION: In connecting the Type 190A to the oscilloscope, be sure to follow the indicated procedure exactly. Do not under any circumstances insert a length of cable between the Type 190A attenuator head and the oscilloscope, or omit using the 10-1 T-Pad. A capacitive load of over 10 μμf presented to the attenuator head of the Type 190A will cause frequency-dependent variations in the output, and render it useless as an amplitude standard.

The T-Pad isolates the 20 μμf load presented by the Type K or L preamplifier from the attenuator head, keeping the 190A output constant.

See your Type 190A instruction manual for further information on proper usage.

15.5 ADJUSTMENT OF VERTICAL AMPLIFIER AND DELAY LINE:

NOTE: The objectives in these adjustments are (1) to obtain transient response free of any overshoot, wrinkles, "bumps" or other aberrations, (2) to obtain vertical system risetime within specifications, and (3) to obtain vertical system bandwidth within specifications. These are listed in the order of their proper consideration for the calibrator. To "go after" the second and third objectives without regard to the first will degrade the usefulness of the scope for its intended purposes.

TIME REQUIRED: A touch-up to correct only minor aberrations in the display can usually be completed within an hour. However, to correct major display aberrations, to completely adjust a new or badly misadjusted delay-line, or to correct the response of an older instrument which has required many component and tube replacements, will usually require about four hours with experience, and up to thirty hours or so without experience. Adjustments should not be undertaken unless they are actually found to be necessary and enough time is available to complete the job satisfactorily.

CAUTION: Plastic coil forms have a tendency to "cold flow" around the adjustable ferrite slugs, over a period of years, causing the slugs to "freeze" in position. If coil adjustments are necessary, the slugs should be loosened first with a metal 5/64" allen wrench, then adjusted with the Type 003-007 alignment tool. Always make sure the wrench or tool is fully engaged in the slug before turning. Otherwise, the slug will probably break, requiring replacement of the slug and possibly of the coil as well. To remove a broken or cracked slug, pick the small pieces out carefully with a scribing tool, and use a moistened Q-tip to clean the coil form threads before replacing. (Q-tip should not be moistened with solvent or "cleaning" fluids; use plain water.)*

PROCEDURE:
1. Analyze transient response according to 15.5.1 to determine adjustments required.
2. Check coil settings per 15.5.2.1.
3. Make coil pre-sets as necessary. (15.5.2.2.)
4. Clean up wrinkles. (15.5.2.3).
5. Measure risetime, repeat 3 and 4 as necessary.
6. Measure bandwidth, repeat 3, 4, and 5 as necessary.

PROPER USE OF TEST INSTRUMENTS: The Type P plug-in should only be used for adjustment of peaking coils and the few delay line trimmer capacitors nearest the CRT. Small wrinkles should be trimmed out using Type K or Type L plug-in, to assure correct response.

*Additional threaded slugs are Tektronix p/n 276-506.

15.5 ADJUSTMENT:

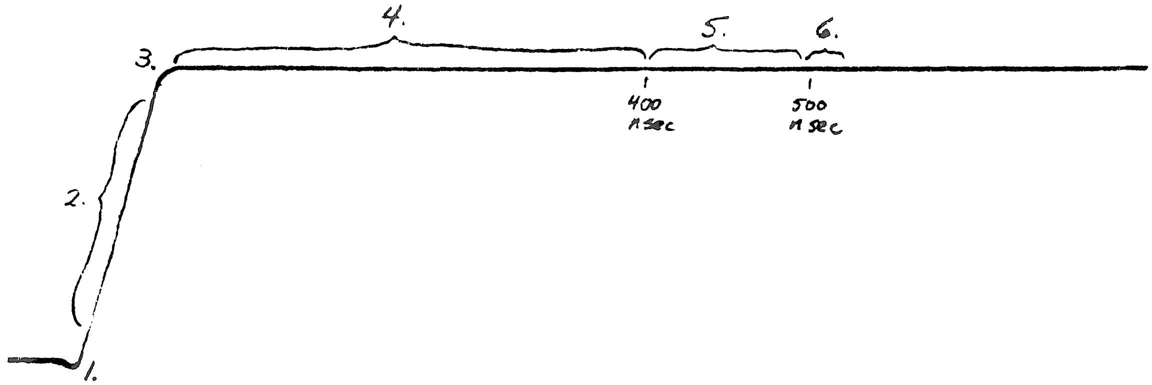
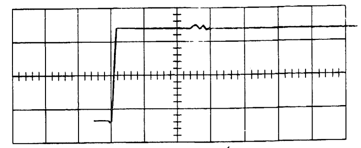


FIG. 15-6. Significant portions of step-function display.

1. "Preshoot" -- normal, if not excessive. About 5% is normal, using Type 107.
2. Risetime, 10% to 90%. Affected primarily by peaking coils in vertical amplifier and at CRT. Exaggerated here. Actual value with P-Unit or fast-rise plug-in, 12 nsec (.012 μsec).
3. "Front corner". Should appear quite square at 200 nsec/cm (0.2 μsec/cm), with no overshoot greater than one tracewidth discernible at any sweep speed. Affected by peaking coils, termination network, and delay-line capacitors nearest CRT.
4. First 400 nsec (approx) of waveform, affected only by delay line in normal instrument. Defective tubes may cause this segment to slope downward to the right. Each delay-line segment will affect a small segment of this part of waveform, the capacitors nearest the CRT affecting segments at the left; those nearest the vertical amplifier affecting segments at the right.
5. 400-500 nsec area: affected primarily by the plate-line capacitors in the distributed amplifier. Each capacitor will affect a small segment of the display in this range.
6. Termination area. This will be primarily affected by adjustments to the reverse termination network capacitors.

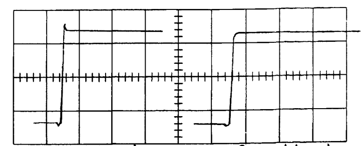
15.5.1 Analysis: Using the Type 107 and a Type (53/54) K or L plug-in, connected as in 15.3, check through the list of aberrations below to determine how extensive a realignment will be required.

A. Excessive Termination Bump: Readjust reverse termination capacitors, plate line capacitors, and 3 or 4 delay-line capcitors nearest to CRT. No coil adjustment, normally.



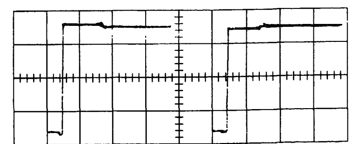
0.2 μsec/cm

B. Slight Spike or Slight Rounding of "Corner": Readjust first few delay-line capacitors nearest CRT. Coil adjustment may also be required.



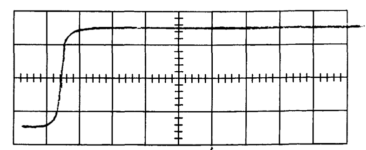
(Spiking) (Rounding)
0.2μsec/cm.

C. First 1/2 μsec Slightly Higher or Lower than Rest of Display: Readjustment of all delay-line and DA capacitors and reverse termination capacitors will be required. Coils are probably OK. Possible termination resistor problem.



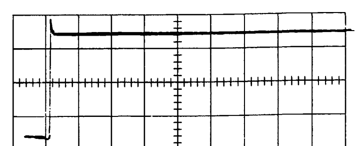
(High) (Low)
0.5μsec/cm.

D. Inadequate Risetime, Inadequate Bandwidth, Rounded Front Corner: Coils and all trimmers will require adjustment. Try adjusting trimmers first.



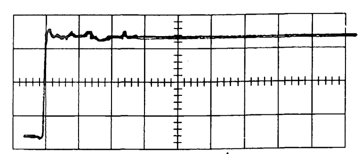
0.1μsec/cm

E. Severe Spiking, "Bandwidth" to More than 30 mc: Coils over-peaked. Will require coil adjustment, perhaps trimmer adjustment as well.*



0.5μsec/cm.

F. Many Wrinkles, Bumps, Irregularities in Display: All trimmers may require adjustment: major realignment indicated.



0.2μsec/cm.

*In one reported case, this was caused by a tube in the D.A. having fallen out of its socket.

15.5.2 Adjustment Steps: Perform as many of the indicated adjustments as may be required. First objective is always a smooth display; second is proper risetime; third is proper bandwidth. (Bandwidth measurement is primarily a check on the accuracy of risetime measurement.)

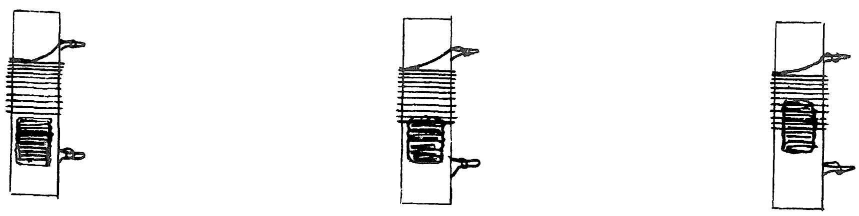
15.5.2.1 Variable Inductors: Check the positions of the slugs in the variable inductors against the settings indicated in the tables below (see also Fig. 15-7). In all cases, both inductors should be set the same, in a given pair. Don't adjust yet.

SERIAL NUMBERS 101-9291 ONLY

Inductors	Slug Setting
Input Plate (Shunt) L1021 and L1042	Half
Input Plate (Series L1022* and L1041*	Edge*
CRT Input L1254 and L1255	Just Out

SERIAL NUMBERS 9292 AND UP ONLY

Inductors	Slug Setting
Input Plate L1014 and L1024	Edge
1st CF Cathode L1036 and L1046	Half
Termination Network L1071 and L1073	Just Out
CRT Input L1354 and L1355	Just Out



"Just Out" "Edge" "Half"

FIG. 15-7 Illustrating coil slug settings called out in 15.5.2.1/15.5.2.2. Slug should be on chassis side of coil, except for CRT input coils, where slug should be on side away from CRT.

15.5.2.2 Variable Inductor Preset: If minor touchup only is indicated in 15.5.1, simply equalize mismatched settings. If slight coil adjustment is indicated in 15.5.1, see that slug settings are approximately as above, particularly L1036 and L1046 in later instruments. If major readjustment is indicated, preset coils to settings indicated in chart above. Later adjustments will determine final settings.

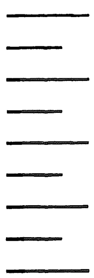
* These are fixed coils (slugs omitted) in some instruments. Do not add slugs to these.

15.5.2.3 Eliminating Wrinkles: For any given coil adjustment, some correction of delay line and distributed amplifier plate line capacitors will probably be required to smooth out transient response and eliminate echoes ("wrinkles") in the step-function response. Use Type 107 Square wave generator, and Type K or L plug-in, connected as in 15.3.

A. To identify the capcitor (s) responsible for any given echo, set sweep Time/cm to .1 μsec/cm and touch the small metal insert of the Type 003-007 alignment tool to the screws in the probable area of the delay line (see Fig. 15.6), watching for a very slight "dip" to appear.

B. Adjustments usually must start at the termination network and proceed toward the CRT. Make only very small adjustments to each capacitor. Any given correction will require small readjustment of several capacitors.

C. Avoid over-correction, resulting in jagged see-saw capacitor adjustments. Except for the three capacitors nearest the CRT, the final positions of the capacitors along the upper section of the delay line (parallel to the CRT) should be fairly even. Along the vertical section of the line, adjustments will follow a pattern similar to that sketched at the left. No screw should be so far out as to extend into the hole in the delay-line shield.



Adjustment Pattern (C)

D. When wrinkles are smoothed out, check the waveform appearance at .2 μsec/cm, .5 μsec/cm and 1 μsec/cm. There should be no tilt or spiking of the leading edge or unevenness in the display at any of these sweep rates. Work over the line as necessary for a "clean" display at each sweep rate, with a good square "corner". The final adjustment should show no wrinkles of more than a trace-width in amplitude.

E. When display is well-corrected, check risetime as in 15.2. If inductor settings must be corrected, capacitor settings - particularly the 5 or 6 nearest the CRT - may also require readjustment.

15.5.2.4 Coil Adjustments: Check risetime as in 15.2, using P Unit. If this is now 12 nsec (.012 μsec), proceed with bandwidth measurement. If not, adjust inductors as indicated below.

A. To increase bandwidth, reduce risetime: Increase the inductance of the CRT input inductors slightly by adjusting the two cores equally a slight amount, further into the coils. This will cause some spiking of the step-function display. Correct the spiking, using the first 5 or 6 delay-line capacitors nearest the CRT. Re-check risetime, and repeat if necessary.

B. If CRT Input Inductor Adjustment Insufficient: Increase slightly the inductance of the (shunt) input amplifier plate peaking inductance. Be sure both inductors are adjusted to equal settings. Correct spiking with delay-line capacitors as before.

C. If "Termination Bump" is excessive (S/N 9292-up only): Make slight adjustments of L1071 and L1073, correcting display aberrations with DA plate-line and termination-network capacitors and capacitors in delay-line nearest the CRT.

D. Final Alignment: Work back and forth between 15.5.2.3 and 15.5.2.4 with frequent risetime checks (15.2) until proper risetime is achieved with no aberrations in the display. Confirm risetime measurement with Type 107 and K (or L) plug-in, and then with Type 190A Sine-Wave Generator (bandpass measurement, 15.4). When final correct adjustment is obtained, the P-Unit display will contain some small wrinkles not evident in the 107/K or 107/L display. This is normal. The final adjustment should provide the cleanest K or L Unit display, with correct risetime by both methods.

15.6 TROUBLESHOOTING: Most common malfunctions and aberrations in the vertical amplifier circuitry will have been cleaned up by tube and component replacements in Steps 7 and 15.1. Listed below are some of the unusual and infrequent failures causing effects only noticeable during fast-rise observations.

15.6.1 Risetime Too Slow for Correction by Adjustment: Open suppressor bypass capacitor(s) in distributed amplifier. Open compensating capacitor across 47 or 33 ohm series resistor in cathode of driver stage. Increase in plate-load resistor in input amplifier stage. Change in input or DA stage cathode or screen resistors. Possibly open 0.68 pf "speedup" (series) capacitors in delay line.

15.6.2. Excessive Spiking, More than 30 mc "Bandwidth": Open Capacitor in plate line.

NOTE: Be sure that "spiking" is not overshoot due to cathode interface (See Step 7.1.3 and Fig 7-4). In instruments below S/N 9292, try removing slugs from L1041 and L1022: These may have been added in error.

15.6.3 Excessive "Termination Bump": Failure of the fixed or variable capacitors or heat damage to R L components in the termination network will cause uncorrectable wrinkle about 1/2 µsec from the leading edge. Replace any out-of tolerance or damaged components.

15.6.4 Oscillations, Severe Single-Frequency Ringing: Check for open bypass capacitor, particularly on filament line or at plate of CF. Failure of 150 pf inter-cathode coupling capacitors in DA may cause oscillations in the 100-200 mc range. Be sure that the (white) trigger pickoff lead is dressed away from signal circuits near the 16 pin interconnecting socket.

NOTE: Certain instruments in the serial range 10,000 to 13,000 tend to oscillate when used with some Type 53/54C and CA plug-ins, sometimes only at extreme positions of the vertical position control. Check the location of C1054, the .005 bypass disc capacitor from the DA common plate supply to ground. If this is located at pin 5 of V1054, remove it and install it between the load end of R1054 (167 Ω, 5 watt) and the ground lug on C1005 adjacent to this terminal. This should eliminate the oscillations.

15.6.5 Miscellaneous Abberations Not Correctable by Adjustment: Possible failure of components in RC balancing networks in delay line.

15.6.6 Step Waveform Tilts Downward to the Left: If the first 1/2 µsec of the waveform tilts downward to the left, giving the appearance of serious "undershoot" at about 5 µsec/cm, it may be due to defective D.A. tubes. (Figure 7-5). Try a new set of tubes.

16 FRONT-PANEL WAVEFORMS.

16.1 SAWTOOTH, MAIN SWEEP:

16.1.1 Check Waveform: Free-run Main Sweep. Using DC-Coupled test-scope, check the amplitude of the sawtooth waveform at each sweep-rate from 1 sec/cm to 10 μsec/cm. Sawtooth should reach approximately +150 v, and return to about 0 v for each sweep. Check linearity of waveform and confirm that at least a portion of the "holdoff" interval between sweeps is evident from the front-panel waveform. Log start and peak voltages in Cal Record.

Now, check sweep rates 1 μsec/cm to .1 μsec/cm. Sawtooth waveform here may not return to zero. A start-point of +20 v, running to about +185 v is typical. Log start and peak voltages in Cal Record.

16.1.2 Troubleshooting: Most aberrations in the front-panel waveform are traceable to a defective V73, output CF. If fast sweeps appear non-linear, try replacing C81. If tube replacements are frequent here, Check C81, R81, and R84 for shorts or severe leakage.

16.2 GATE WAVEFORMS:

16.2.1 +Gate Main Sweep: Use test scope to observe output of front-panel connector. Gate waveform at all sweep rates should be 20 v minimum, but not over about +35 v. Waveform should return each time to 0v between sweeps. Check the waveform, especially for a flat bottom. At fastest sweeps, some rounding of the front corner and a 1/2 μsec notch following the front corner will normally be evident. Log proper operation in Cal Record.

16.2.2 +Gate, Del'g Sweep: Proceed as before, free-running the delaying sweep, and examining the output waveform at the front panel connector with the test scope. Minimum amplitude should be 20 v. Log in Cal Record.

16.2.3 Troubleshooting: Unless there is some aberration apparent in the beam-brightening (unblanking) of the CRT, any malfunctions will probably be in V73 (Main Sweep) or V172 (Delaying Sweep) circuits, these being the output CF's. If simple tube replacement does not work, check the grid-divider circuits and cathode resistor of the tube associated with the defective output.

16.3 6.3 VAC CONNECTOR:

16.3.1 Check Output: Measure output at 6.3 VAC output connector. This should be 17.8 v peak-to-peak for 117 v line input. In later scopes and early instruments that have been modified, the source impedance will be 100 Ω. In early instruments that carry the "1 amp" panel marking, there is a 1-ampere fuse wire in series with the output. Be careful not to short this connector to ground, even momentarily.

16.3.2 Troubleshooting: If there is no output at this connector, install a 100 Ω 1/2 watt resistor from the "hot" side of the panel light socket and the connector, in place of a fuse. Replacing the fuse wire will only be necessary where the full 1-amp capability is required, as in powering an external relay or camera solenoid.

17 Z-AXIS INPUT.

17.1 MEASUREMENT: Remove cathode-input strap between ground and cathode input terminals at the rear of the instrument. Using coax or a long test lead, patch from the Cal Out connector to the Cathode input terminal, and also to the Trigger Input terminal for the Main Sweep. Trigger the sweep on +Ext, at about 1 msec/cm. Increase Calibrator output to 20 v. Alternate segments of the sweep should be completely blanked out at normal viewing intensity. Check Cal Record if operation is normal.

17.2 SAFETY CHECK: Remove patch set up in 17.1. Patch voltmeter between ground and Cathode input terminal, and turn off the sweeps. There should be no voltage reading. If any voltage reading appears, leaky C857 (.015, 3kv) should be replaced, to avoid possible shock hazard.

18 MISCELLANEOUS PERFORMANCE NOTES.

This segment of the calibration record is reserved for notes which may be of help to instrument operators and future calibrators in making best use of the instrument and in maintaining it better:

Some things which typically might be noted here:

Instrument peculiarities.

Progressive conditions that may require future attention.

Notations of physical damage (nicks, scratches, dents, etc.).

Temporary parts replacements (as where exact parts not available).

Calibration steps skipped because of lack of time or equipment.

.oOo.

SECTION 4

CALIBRATION RECORD

____
Organization

____
Department

Type 545 Oscilloscope

Serial No.__________

Calibrated__________

Re-Cal Due Date____

By:______________

1. PHYSICAL CHECKOUT.

PARTS REPLACED

1.1	Damage Check	________
1.2	Air Filter: Condition	________
	Washed	________
	Treated	________
1.3	Fan Motor: Condition	________
	Oiled	________
1.4	Clean HV, CRT	________
1.5	Graticule, Etc.	________
1.6	Fuse Size	______ A.

2. POWER SUPPLY.

2.1 Resistance to Ground (No Plug-In):

-150 v__________ Power Leads________
+100 v__________ Xfmr Primary________
+225 v__________
+350 v__________
+500 v__________

2.2 Relay Operation:

Delay ______ sec.
Contacts__________
Armature__________

2.3 Low Voltage Regulated Supplies:

Supply		-150 v	+100 v	+225 v	+350 v	+500 v	
2.3.1.1	Voltage	______	______	______	______	______	(v)
2.3.1.2	Ripple	______	______	______	______	______	(mv)
2.3.1.3	Dropout	______	______	______	______	______	(vac)
2.3.1.4	DC Input	______	______	______	______	______	(v)
2.3.1.5	Current	______	______	______	______	______	(ma)
2.3.2.1	Adj?	______					

2.4 Elevated Filament Lines:

Xfmr Terminals	22/23	27/28	9/16	24/25
Normal	+100 v	+225 v	+350	- H.V.
Measured	______	______	______	______

	PARTS REPLACED
3. SQUARE-WAVE CALIBRATOR.	
3.1 Test Point Voltage (DC meter)	
3.1.1 DC Reference (Cal "Off")	______v
3.1.2 Symmetry (Cal "On")	______v
3.2 Adjustment required?	______
4. HIGH VOLTAGE SUPPLIES.	
4.1 Operation and Regulation:	
4.1.1 H.V. Test Point	______v
4.1.2 Cathode Supply Regulation:	
4.1.2.1 High Line, Low Load	______v
4.1.2.2 Low Line, High Load	______v
4.1.3 Grid Supply	______v
4.2 Adjustment required?	______
5. MISCELLANEOUS FUNCTIONS.	
5.1 Beam Position Indicators: Vert.	______
Horiz.	______
5.2 Horizontal Position Controls:	______
5.3 Alternate Sweep Sync:	______
6. CRT. F and I CIRCUITS.	
6.1 CRT Alignment:	______
6.2 CRT Condition:	______
6.3 CRT Geometry: Vertical Lines:	______
Horizontal Lines:	______
6.3.2 Adjustment Required?	______
6.4 (if New CRT Installed) Serial No.	______
Date Code	______
6.4.1.1 Alignment and Condition	______
6.4.1.2 Geometry reset	______
6.4.1.3 Vertical Deflection Factor	______v/cm
6.4.1.3 Vertical Plate Sheield	______v
6.4.2.2 Age-In required?	______

7. VERTICAL AMPLIFIER (Initial Alignment).

PARTS REPLACED

7.1 Vertical Amplifier Precheck:
- 7.1.1 Microphonics ________ mm
- 7.1.2 Input Stage Check ________
- 7.1.3 Interface Check ________

7.2 Vertical Balance: Log+ or – Imbalance as indicated.

7.2.1 Overall Imbalance: Initial ________ mm
Final ________ mm

7.2.2 Balancing:
- 7.2.2.1 DA Grids Shorted ________ mm
- 7.2.2.2 DA Bias (Highest) ________ v
  (Lowest) ________ v
- 7.2.2.3 Corrected DA Balance ________ mm
- 7.2.2.4 Driver Stage (Initial) ________ mm
  (Final) ________ mm
- 7.2.2.5 Input Stage (Initial ________ mm
  (Final) ________ mm

7.3 Linearity (Final): Compression ________ mm
Expansion ________ mm

7.4 D.C.Shift:

7.4.1 Initial Shift (log + or –) ________ mm
7.4.2 Final Shift after adjustment ________ mm

7.5 Drift With Line Voltage Change:

7.5.1 Final Drift ________ mm

7.6 Vertical Signal Output: ________ v/cm

7.7 Gain:

7.7.1 Maximum Gain (200 mv input) ________ cm
7.7.2 Gain Set ________

8. CALIBRATOR DIVIDER.

8.1 Accuracy Check: Plug-In Type ________
Serial No. ________
Channel ________
Maximum Discrepancy (High) (Low) ________ %
(Calibrator Step) ________

8.2 Error Confirmation: Plug-In Type ________
Serial No. ________
Channel ________
Actual Error (High) (Low) ________ %

8.3 Final Maximum Error: (High)(Low) ________ %
(Calibrator Step) ________

PARTS REPLACED

9. TRIGGER CIRCUITS, MAIN SWEEP:

9.1 Preliminary Checkout: __________

9.2 Realignment:

9.2.1 Triggering Level Knob Zero __________
9.2.2 V8 Gas Check __________
9.2.3 Internal Adjustments
9.2.3.1 Trigger Level Centering __________
9.2.3.2 D. C. Level Adj. __________
9.2.3.3 Touch-Up __________
9.2.3.4 Trigger Sensitivity __________
9.2.3.5 Touch-Up __________
9.2.3.6 Preset Stability __________
9.2.4 Automatic Operation

9.3 Final Checkout: (Log miminum trigger or display allowing slope-switching)

Cal Waveform, Internal.	DC	__________mm
	AC Slow	__________mm
	AC Fast	__________mm
	Automatic	__________mm
Cal Waveform, External.	DC	__________mv
	AC Slow	__________mv
	AC Fast	__________mv
	Automatic	__________mv
60-cycle Display, Int.	DC	__________mm
	AC Slow	__________mm
	Automatic	__________mm

9.4 H.F.Sync Operation: __________

10. TRIGGER CIRCUITS, DELAYING SWEEP.

10.1 DC Balance: __________

10.2 Preliminary Checkout __________

10.3 Realignment:

10.3.1 Triggering Level Knob Zero __________
10.3.2 V113 Gas Check __________

10.4 Final Checkout: (Log minimum values)

Cal Waveform, "Internal" Minimum __________mm
Mimimum for Slope-Switching __________mm

60-cycle, "Internal" Minimum __________mm
Minimum for Slope-Switching __________mm

Cal Waveform, "External" Minimum __________mv

COMPONENTS REPLACED

11. SWEEP CALIBRATION.

11.1.1	Sweep Calibration, Initial Error		______%	
	11.1.1.2 Sweep Cal Adj		______	
11.1.2	Magnifier, Initial Error			
	Linearity Check		______%	
	11.1.2.2 Mag Gain Adj		______	______
11.1.3	Sweep/Mag Regis Adj		______	
11.1.4	Sweep Amplifier Check		______	
11.1.5	Main Sweep, Initial Error		______%	
	11.1.5.2 Main Sweep Vernier Adj		______	
11.1.6	Main Sweep Length Adj		______	
11.1.7	Sweep Amp Fast Sweep Check		______	
11.1.8	Delaying Sweep Length	Max	______cm	
		Min	______cm	______
11.1.9	Sweep Ampl. Gain		______v/cm	______
11.3.1	Slow Sweeps, Main Sweep			
	Error, 100 μsec/cm		______%	
	200 μsec/cm		______%	
	500 μsec/cm		______%	
	Variable Multiplier CW, 2.5-1		______	
	CCW, 2.5-1		______markers	
	CCW, 5-2		______markers	
	CCW, 12-5		______markers	
	Control Operation:		______	
	Error, 10 msec/cm		______%	
	100 msec/cm		______%	
	1 sec/cm		______%	
	2 sec/cm		______%	______
	5 sec/cm		______%	______

11.4 Fast Sweeps, Main Sweep.

	Initial	Final
Error, 10 μsec/cm	____%	____%
1 μsec/cm	____%	____%
2 μsec/cm	____%	____%
5 μsec/cm	____%	____%
.02 μsec/cm Center	____%	____%
.02 μsec/cm Start	____%	____% (Skip 5 cy)
.02 μsec/cm Start	____%	____% (Skip 3 cy)
.02 μsec/cm End	____%	____%

11.5 Horiz. Ampl. Input Compensation.

C110 ______
C100 ______
C101 ______

COMPONENTS REPLACED

12. DELAY AND LOCKOUT SYSTEM.

12.1 Delayed Trigger Check: From MS ________v min
From DS ________v min

12.2 Lockout Level (R64) Set: ________

12.3 Single-Sweep Check:
Manual ________
Triggered ________
Reset ________
Rate Gen. ________

12.4 Pickoff Drift, 5 sec: ________mm

12.5 Delay Start/Stop:

Initial:
Start ________(dial)
Stop ________(dial)

Final:
1 cm 1.00
2 cm ________
3 cm ________
4 cm ________
5 cm ________
6 cm ________ ________
7 cm ________ ________
8 cm ________ ________
9 cm 9.00 ________

13. DELAYING SWEEP CALIBRATION.

13.1 Slow Sweep Check:

Dial Reading at 9 cm marker:
200 μsec ________
500 μsec ________
1 msec ________
2 msec ________
5 msec ________
10 msec ________ ________

13.2 Fast Sweep Check and Cal:

Dial Reading at Marker:	1 cm	9 cm Initial	9 cm Final	
50 μsec/cm	________	________	________	
100 μsec/cm	________		________	
20 μsec/cm	________		________	
5 μsec/cm	________	________	________	
10 μsec/cm	________		________	
2 μsec/cm	________		________	________

13.3 Fast Sweep Linearity:

Maximum Dial Error
50 μsec/cm ________at________cm
5 μsec/cm ________at________cm

13.4 Jitter at 1000-1 Sweep Ratio:

At 1 cm delay ________mm
At 9 cm delay ________mm ________

COMPONENTS REPLACED

14. HOLDOFF TIMES.

Main Sweep 1 sec/cm -

Main Sweep 1 sec/cm -	100 msec/cm	________	
	10 msec/cm	________	
	1 msec/cm	________	
	100 μsec/cm	________	
	10-1 μsec/cm	________	
	0.1 μsec/cm	________	________
Delaying Sweep	10-2 msec/cm	________	
1 msec --	200 μsec/cm	________	
	100-20 μsec/cm	________	
	10-2 μsec/cm	________	________

15. VERTICAL AMPLIFIER AND DELAY LINE COMPENSATION.

15.1.1 Tube Condition Recheck ________

15.2 With P-Unit, S/N ________

Risetime ________nsec

Response ________ ________

15.3 With 107, S/N ________ and (K) (L) S/N________

Risetime ________nsec

Response ________ ________

15.4 With 190 (A), S/N________

-3db point ________mc

Deflection at 30 mc ________%

16. FRONT-PANEL WAVEFORMS.

Main Sweep Sawtooth, 1 sec/cm - 10 μsec/cm ______ - ______v

1 - .1 μsec/cm ______ - ______v

Main Sweep Gate ______v min

Delaying Sweep Gate ______v min ________

6.3 V AC (17.8 v p-p) ______v p-p________

17. Z-AXIS INPUT: 20 v Cal Waveform Check ______.

18. MISCELLANEOUS PERFORMANCE NOTES:

____

____

____

____

____

SECTION 5

PARTS LISTS

0 RECOMMENDED TUBE AND RECTIFIER SPARES FOR REPLACEMENT AND COMPARISON PURPOSES.

0.1 TEKTRONIX, INC. SELECTED AND AGED TUBES:

Serial No. Range 101-9291: 2 ea P/N 157-039 6AW8*
14 ea P/N 157-037 6CB6

Serial No. Range 9292-up: 2 ea P/N 157-053 12BY7A*

*Both tubes should carry same subgroup No.

0.2 STANDARD COMMERCIAL "RAW" TUBES (Brand preferences as noted):

Serial No. Range 9292-up: 14 ea 6DK6, Tektronix p/n 154-149, (Special G-E), or RCA commercial type. Other brands not recommended.**

All Serial Ranges:
4 ea 6DJ8/ECC88 or 6922/E88CC***
4 ea 6AU6
4 ea 6U8A, if used as V20 etc, otherwise 2 ea.
2 ea 6080, 12B4, 5642.
1 ea 6AU5, 6AL5, 6CL6, 5651, 12AL5, 12AU6, 12AU7, 12AX7 and 12BY7A.

**Note on Type 6DK6 tubes: 6DK6's tend to develop "cathode interface" after several hundred hours' operation, causing overshoot in the scope display of step waveforms. Some brands of tubes develop this defect quickly, others show very little even after a year's operation. Tektronix, Inc. will supply whatever brand currently exhibits the best performance record in this respect. Those presently (1961) being furnished are being made specially for Tektronix by G-E.

***These tubes are a direct replacement for Type 6BQ7A used in early instruments, at a considerable increase in reliability. If foreign-made tubes are unavailable to you, maintain 6BQ7A stocks as follows: 8 ea "raw" 6BQ7A (Sylvania) and 2 ea, Tektronix, Inc. selected and aged 6BQ7A, P/N 157-022 for use in horizontal output circuits (V265 & V272.)

Tube stocks maintained at indicated levels should be adequate for 1-6 instruments. Tube stocks should be considerably larger at the start of a recalibration program, however, as instruments neglected for a long period may require large-scale tube replacements.

0.3 CATHODE RAY TUBES: Projected lifetime of CRT's in normal use is 3-5 years. Shelf life, however, is only 1-2 years without periodic activation, so prolonged storage of spares is not recommended. See section 6.4.2.2.

0.4 SELENIUM RECTIFIERS: Further stocking of selenium rectifiers is not recommended: Full replacement with silicon types is suggested after first selenium failure in an instrument. Projected normal selenium lifetime in use is 2-4 years. Modification kit 040-239 replaces all selenium rectifiers with silicon diodes. The complete kit is priced about the same as a full set of seleniums.

All changes made to Type 545 at SN 9292 were incorporated in RM45, SN 101

Capacitors

Effective SN							
	C1	4.7 µµf	Cer.	Fixed	500 v	±1 µµf	281-501
	C3	.001 µf	PT	"	600 v	20%	285-501
	C4	100 µµf	Cer.	"	350 v	"	281-523
	C7	.001 µf	Cer.	"	500 v	GMV	283-000
	C9	47 µµf	Cer.	"	"	20%	281-518
	C17	.001 µf	Cer.	Fixed	500 v	GMV	283-000
	C20	.01 µf	PT	"	400 v	20%	285-510
Added 9403 & up	C22	.01 µf	Cer.	"	500 v	GMV	283-002
	C28	.001 µf	Cer.	"	"	"	283-001
	C34	22 µf	Cer.	"	"	20%	281-510
	C37	.001 µf	Cer.	"	"	GMV	283-000
	C40	.005 µf	Cer.	Fixed	500 v	GMV	283-001
	C41	.005 µf	Cer.	"	"	"	283-001
	C45	.001 µf	Cer.	"	"	"	283-000
	C50	8 µµf	Cer.	"	"	±0.5 µµf	281-503
	C54A	.22 µf	PT	"	400 v	20%	285-533
	C54B	.022 µf	PT	Fixed	400 v	20%	285-515
	C54C	.0022 µf	PT	"	"	"	285-543
	C54D	220 µµf	Mica	"	500 v	10%	283-536
	C56	39 µµf	Cer.	"	"	"	281-516
	C58	27 µµf	Cer.	"	"	20%	281-513
	C65	12 µµf	Cer.	Fixed	500 v	10%	281-506
	C71	82 µµf	Cer.	"	"	"	281-528
Added 5117 & up	C72	.005 µf	Cer.	"	"	GMV	283-001
	C73	12 µµf	Cer.	"	"	10%	281-506
	C76	.005 µf	Cer.	"	"	GMV	283-001
	C78	.005 µf	Cer.	"	"	GMV	283-001
	C81	.001 µf	Cer.	"	"	"	283-000
	C95	.001 µf	Cer.	"	"	"	283-000
	C96	82 µµf	Cer.	"	"	10%	281-528
	C99A	1.0 µf	)				
	C99B	.1 µf	)	Main Sweep Timing Series			291-007
	C99C	.01 µf	)				
	C99D	.001 µf	Mylar				291-008
	C99E	82 µµf	Mica	Fixed	500 v	5%	283-534
	C99F	4.5-25 µµf	Cer.	Var.	500 v	20%	281-010
	C99G	82 µµf	Mica	Fixed	"	5%	283-534
	C99H	4.5-25 µµf	Cer.	Var.	"	20%	281-010
	C99J	3-12 µµf	Cer.	Var.	"	20%	281-007
101 - 7329	C100	5-25 µµf	Cer.	Var.	"		281-011
7330 & up	C100	8-50	Cer.	Var.	"		281-013
	C101	5-25 µµf	Cer.	Var.	500 v		281-011
	C102	100 µµf	Cer.	Fixed	"	10%	281-530
	C108	.001 µf	Cer.	"	"	GMV	283-000
	C110	5-25 µµf	Cer.	Var.	"		281-011
	C132	22 µµf	Cer.	Fixed	"	20%	281-510

Capacitors Cont.

	C146	47 µµf	Cer.	Fixed	500 v	20%	281-518
	C148A	.047 µf	PT	"	400 v	20%	285-519
	C148B	.0047 µf	PT	"	400 v	20%	285-506
	C148C	470 µµf	Cer.	"	500 v	20%	281-525
Added 5138 & up	C148D	22 µµf	Cer.	"	500 v	20%	281-510
	C158	12 µµf	Cer.	Fixed	500 v	10%	281-506
	C170	39 µµf	Cer.	"	500 v	10%	281-516
	C172	12 µµf	Cer.	"	"	"	281-506
	C187	.001 µf	Cer.	"	"		283-000
	C190A	.0505 µf)	Delaying Sweep Timing Series				291-006
	C190B	.00505 µf)					
	C190C	450-475 µµf)					
101 - 8179	C190D	8-50 µµf	Cer.	Var.	500 v		281-013
8180 & up	C190D	7-45 µµf	Cer.	Var.	500 v		281-012
	C190E	39 µµf	Mica	Fixed	500 v	5%	283-533
101 - 8179	C190F	3-12 µµf	Cer.	Var.	500 v		281-009
8180 & up	C190F	3-12 µµf	Cer.	Var.	500 v		281-007
	C191	.01 µf	PT	Fixed	400 v	20%	285-510
	C197	220 µµf	Mica	"	500 v	10%	283-536
	C209	.01 µf	Cer.	Fixed	500 v	20%	283-002
	C218	22 µµf	Cer.	"	"	"	281-510
	C228	47 µµf	"	"	"	"	281-518
Added 5125 & up	C232	.005 µf	"	"	"	"	283-001
1 - 618	C235	12 µµf	"	"	"	~~281/506~~ Use	281-510
619 & up	C235	22 µµf	"	"	"	20%	281-510
	C236	.001 µf	"	"	"	GMV	283-000
101 - 14,543	C240	3-12 µµf	Cer.	Var.	500 v	~~281/007~~ Use	281-010
14,544 & up	C240	4.5-25 µµf	Cer.	"	"		281-010
	C241	4.7 µµf	"	Fixed	"	±1 µµf	281-501
Added 14,223 & up	C245	.68 µµf	"	"	"	±.136	281-537
101 -13,343	C249	.01 µf	PT	"	400 v	20%	285-510
13,344 & up	C249	Deleted					
	C254	3-12 µµf	Cer.	Var.	500 v		281-007
	C258	1.5 µµf	"	Fixed	"	±½ µµf	281-526
	C267	9-180 µµf	Mica	Var.	500 v		281-023
	C273	6.25 µf	EMC	Fixed	300 v		290-000
	C278	3-12 µµf	Cer.	Var.	500 v		281-009
	C282	.047 µf	PT	Fixed	400 v	20%	285-519
	C284	4.7 µµf	Cer.	"	500 v	±1 µµf	281-501
	C286	3-12 µµf	"	"	"		281-009
Added 13,344 & up	C292	.005 µf	"	"	"		283-001
	C672	330 µµf	Mica	Fixed	500 v	10%	283-518
	C673	330 µµf	"	"	"	"	283-518
	C682	27 µµf	Cer.	"	"	20%	281-513
	C695	.001 µf	"	"	"	GMV	283-000
	C700	.02 µf	"	"	250 v	GMV	283-004

Note: Changes made to Type 545 at SN 14,544 were made to RM 45 at SN 439.
Changes made to Type 545 at SN 13,344 were made to RM 45 at SN 306.
Changes made to Type 545 at SN 14,223 were made to RM 45 at SN 419

Capacitors Cont.

	C707	.01 µf	PT	Fixed	400 v	±1 µµf	285-510
	C711	.01 µf	PT	"	400 v	20%	285-510
	C715	2x40 µf	EMC	"	250 v		290-040
	C717	.01 µf	PT	"	400 v	20%	281-510
Added 5448 & up	C720	.01 µf	Cer.	"	500 v	GMV	283-002
	C732	125 µf	EMC	Fixed	350 v		290-044
	C740	150 µf	EMC	"	250 v		290-048
	C741	150 µf	EMC	"	250 v		290-048
	C750	.01 µf	PT	"	400 v	20%	285-510
	C751	3x10 µf	EMC	"	450 v		290-033
	C756	125 µf	EMC	Fixed	450 v		290-045
	C763	.01 µf	PT	"	400 v	20%	285-510
	C770	.01 µf	PT	"	400 v	20%	285-510
	C780	125 µf	EMC	"	350 v		290-044
	C787	.01 µf	PT	"	400 v	20%	285-510
	C790A,B	2x40 µf	EMC	Fixed	450 v		290-042
	C797	.01 µf	PT	"	400 v	20%	285-510
	C800	.047 µf	PT	"	400 v	20%	285-519
	C803	.001 µf	PT	"	600 v	20%	285-501
	C805	.01 µf	PT	"	400 v	20%	285-510
	C806	.001 µf	PT	Fixed	600 v	20%	285-501
	C807	2x20 µf	EMC	"	450 v		290-037
	C814	.0068 µf	PT	"	3000 v	20%	285-508
	C815	.01 µf	Cer.	"	500 v	GMV	283-002
	C820	.0068 µf	PT	"	3000 v	20%	285-008
	C821	.0068 µf	PT	Fixed	5000 v	20%	285-509
	C822	.00047 µf	PT	"	10000 v	20%	285-500
	C823	.00047 µf	PT	"	10000 v	20%	285-500
	C830	.0068 µf	PT	"	3000 v	20%	285-508
	C832	.015 µf	PT	"	3000 v	20%	285-513
	C834	.015 µf	PT	Fixed	3000 v	20%	285-513
	C841	.015 µf	Cer.	"	500 v	GMV	283-001
	C855	.015 µf	PT	"	3000 v	20%	285-513
	C857	.015 µf	PT	"	3000 v	20%	285-513
Added 9292 & up	C1003	2x20 µf	EMC	"	450 v		290-036
Added 9292 & up	C1005A	40 µf)					
Added 9292 & up	C1005B	20 µf)	EMC	Fixed	475 v		290-063
Added 9292 & up	C1005C	10 µf)					
Added 9292 & up	C1007	.1 µf	PTM	"	400 v	20%	285-526
101 - 9291	*C1010	.005 µf	Cer.	"	500 v	GMV	283-001
Added 9292 & up	C1013	.005 µf	Cer.	Fixed	500 v	GMV	283-001
101 - 9291	*C1014	.005 µf	Cer.	"	"	"	283-001
Added 9292 & up	C1015	.005 µf	Cer.	"	"	"	283-001
101 - 9291	*C1020	.005 µf	Cer.	"	"	"	283-001
Added 9292 & up	C1029	.001 µf	Cer.	"	"	"	283-000
Added 9292 & up	C1030	.005 µf	Cer.	Fixed	500 v	GMV	283-001
Added 9292 & up	C1031	.005 µf	Cer.	"	"	"	283-001
Added 9292 & up	C1033	.005 µf	Cer.	"	"	"	283-001
101 - 9201	*C1035	.005 µf	Cer.	"	"	"	283-001

NOTE: *Circuit numbers DELETED - SN 9292 & up

Capacitors Cont.

Add 9292 & up	C1039	.001 µf	Cer.	Fixed	500 v	10%	281-536
101 thru 9291	*C1045	2x75 µf	EMC	Fixed	150 v	-20+50%	290-053
Add 9292 & up	C1049	.001 µf	Cer.	Fixed	500 v	10%	281-536
101 thru 9291	*C1050	2x75 µf	EMC	Fixed	150 v	-20+50%	290-053
101 thru 9291	*C1051	.005 µf	Cer.	Fixed	500 v	GMV	283-001
101 thru 9291	C1052	.001 µf	Cer.	Fixed	500 v	10%	281-536
9292 & up	C1052	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	C1054	.001 µf	Cer.	Fixed	500 v	10%	281-536
9292 & up	C1054	.005 µf	Cer.	Fixed	500 v	GMV	283-001
101 thru 1077	C1055	.022 µf	PT	Fixed	400 v	~~285-515~~ USE	285-517
1078 thru 9291	*C1055	.022 µf	PT	Fixed	600 v	20%	285-517
Add 9292 & up	C1056	150 µµf	Cer.	Fixed	500 v	20%	281-524
101 thru 9291	*C1057	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1060	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	C1062	150 µµf	Cer.	Fixed	500 v	20%	281-524
9292 & up	C1062	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1064	.005 µf	Cer.	Fixed	500 v	GMV	283-001
101 thru 9291	*C1066	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1070	100 µµf	Cer.	Fixed	350 v	20%	281-523
101 thru 9291	*C1072	12 µµf	Cer.	Fixed	500 v	10%	281-506
101 thru 9291	*C1073	1-8 µµf	Tub.	Var.	500 v		281-003
101 thru 354	C1074	10 µµf	Cer.	Fixed	500 v	10%	281-504
355 thru 9291	*C1074	4.7 µµf	Cer.	Fixed	500 v	10%	281-501
101 thru 9291	C1075	1-8 µµf	Tub.	Var.	500 v		281-003
9292 & up	C1075	8-50 µµf	Cer.	Var.			281-022
101 thru 9291	*C1076	1-8 µµf	Tub.	Var.	500 v		281-003
101 thru 9291	C1077	1-8 µµf	Tub.	Var.	500 v		281-003
9292 & up	C1077	8-50 µµf	Cer.	Var.			281-022
Add 355 thru 9291	C1078	2.2 µµf	Cer.	Fixed	500 v	$\pm\frac{1}{2}$µµf	281-500
9292 & up	C1078	.7-3 µµf	Tub.	Var.			281-027
101 thru 9291	*C1081	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1082	150 µµf	Cer.	Fixed	500 v	20%	281-524
101 thru 9291	*C1083	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1084	.7-3 µµf	Tub.	Var.	500 v		281-027
Add 9292 & up	C1085	.005 µf	Cer.	Fixed	500 v	GMV	283-001
Add 9292 & up	C1089	.005 µf	Cer.	Fixed	500 v	GMV	283-001
101 thru 9291	*C1090	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1091	150 µµf	Cer.	Fixed	500 v	20%	281-524
101 thru 9291	*C1092	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	C1093	.7-3 µµf	Tub.	Var.	500 v		281-027
9292 & up	C1093	4 x 75 µf	EMC	Fixed	150 v		290-071
101 thru 9291	*C1100	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1101	150 µµf	Cer.	Fixed	500 v	20%	281-524
	C1102	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1103	.7-3 µµf	Tub.	Var.	500 v		281-027

Note: *Circuit numbers DELETED S/N 9292 & up

TYPE 545

Capacitors Cont.

Add 9292 & up	C1104	.7-3 µµf	Tub.	Var.			281-027
Add 9292 & up	C1105	150 µµf	Cer.	Fixed	500 v	20%	281-524
Add 9292 & up	C1106	150 µµf	Cer.	Fixed	500 v	20%	281-524
101 thru 9291	*C1110	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1111	150 µµf	Cer.	Fixed	500 v	20%	281-524
	C1112	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1113	.7-3 µµf	Tub.	Var.	500 v		281-027
101 thru 9291	*C1120	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1121	150 µµf	Cer.	Fixed	500 v	20%	281-524
	C1122	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1123	.7-3 µµf	Tub.	Var.	500 v		281-027
Add 9292 & up	C1124	.7-3 µµf	Tub.	Var.	500 v		281-027
Add 9292 & up	C1126	150 µµf	Cer.	Fixed	500 v	20%	281-524
101 thru 9291	*C1130	.001 µf	Cer.	Fixed	500 v	GMV	283-000
	C1132	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1133	.7-3 µµf	Tub.	Var.	500 v		281-027
101 thru 9291	*C1141	.005 µf	Cer.	Fixed	500 v	GMV	283-001
Add 9292 & up	C1142	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1144	.7-3 µµf	Tub.	Var.	500 v		281-027
Add 9292 & up	C1146	150 µµf	Cer.	Fixed	500 v	20%	281-524
101 thru 9291	*C1150	2x20 µf	EMC	Fixed	450 v	-20+50%	290-036
101 thru 9291	*C1151	2x20 µf	EMC	Fixed	450 v	-20+50%	290-037
101 thru 5000	C1152	.005 µf	Cer.	Fixed	500 v	GMV	283-001
5001 thru 9291	C1152	.1 µf	PTM	Fixed	400 v	20%	285-526
9292 & up	C1152	.001 µf	Cer.	Fixed	500 v	GMV	283-000
101 thru 9291	*C1153	2x20 µf	EMC	Fixed	450 v	-20+50%	290-037
101 thru 9291	**C1155	.005 µf	Cer.	Fixed	500 v	GMV	283-001
101 thru 9291	*C1161	.005 µf	Cer.	Fixed	500 v	GMV	283-001
Add 9292 & up	C1162	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1164	.7-3 µµf	Tub.	Var.	500 v		281-027

Note: *Circuit numbers DELETED - SN 9292 & up
**Note: In some Manuals Parts Lists this was C1160.

Add 9292 & up	C1166	150 µµf	Cer.	Fixed	500 v	20%	281-524
Add 9292 & up	C1172	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1182	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1184	.7-3 µµf	Tub.	Var.	500 v		281-027
Add 9292 & up	C1186	150 µµf	Cer.	Fixed	500 v	20%	281-524
Add 9292 & up	C1192	.001 µf	Cer.	Fixed	500 v	GMV	283-000

C1201 thru 1282 for SN's 101-9291, see page 6.

Add 9292 & up	C1202	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1204	.7-3 µµf	Tub.	Var.	500 v		281-027
Add 9292 & up	C1205	150 µµf	Cer.	Fixed	500 v	20%	281-524
Add 9292 & up	C1208	.005 µf	Cer.	Fixed	500 v	GMV	283-001
Add 9292 & up	C1212	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1220	.005 µf	Cer.	Fixed	500 v	GMV	283-001
Add 9292 & up	C1223	.001 µf	Cer.	Fixed	500 v	GMV	283-000
Add 9292 & up	C1228	.022 µf	PTM	Fixed	600 v	20%	285-517

TYPE 545

Capacitors Cont.

SN101 thru 9291 Delay Line

101 thru 9291	C1201-50	.7-3 µµf	Tub.	Var.	500 v		281-027
101 thru 9117	C1260-75	3.3 µµf	Cer.	Fixed	500 v	±¼ µµf	281-534
9118 thru 9291	C1260-75	1.5 µµf	Cer.	Fixed	500 v		281-526
101 thru 9291	C1280	.68 µµf	Cer.	Fixed	500 v	20%	281-537
101 thru 582	C1281	.68 µµf	Cer.	Fixed	500 v	20%	281-537
583 thru 9117	C1281	Deleted					
9118 thru 9291	C1281	.68 µµf	Cer.	Fixed	500 v	20%	281-537
101 thru 9291	C1282	1 µµf	Cer.	Fixed	500 v	20%	281-538

SN9292 & up Delay Line

9292 & up	C1301-50	.7-3 µµf	Tub.	Var.	500 v		281-027
9292 & up	C1360-75	1.5 µµf	Cer.	Fixed	500 v	0.25 µµf	281-529
9292 & up	C1380	.68 µµf	Cer.	Fixed	500 v	20%	281-537
9292 & up	C1381	.68 µµf	Cer.	Fixed	500 v	20%	281-537
9292 & up	C1382	1 µµf	Cer.	Fixed	500 v	20%	281-538
Added 9534 & up	C1384	.68 µµf	Cer.	Fixed	500 v	20%	281-537
" " " "	C1385	.68 µµf	Cer.	Fixed	500 v	20%	281-537

Resistors

	R1	1 meg	1/2 w	Fixed	Comp.	5%	301-105
	R2	390 k	1/2 w	Fixed	Comp.	5%	301-394
	R3	50 k	2 w	Var.	Comp.	20%	311-023
	R4	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R5	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R6	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R7	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R8	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R9	4.7 k	1 w	Fixed	Comp.	10%	304-472
	R10	4.7 k	1 w	Fixed	Comp.	10%	304-472
	R11	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R12	33 k	2 w	Fixed	Comp.	10%	306-333
	R13	39 k	2 w	Fixed	Comp.	10%	306-393
101 thru 7400	*R14	100 k	1/2 w	Var.	Comp.	20%	311-030*
	*Note:	R14 concentric with R43 (Instruments without Preset Stability)					
7401 & up	**R14	100 k	1/2 w	Var.	Comp.	20%	311-096
	**Note:	R14 concentric with R43 (Instruments with Preset Stability)					
	R15	22 k	1/2 w	Fixed	Comp.	10%	302-223
	R16	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R17	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R19	56 k	1/2 w	Fixed	Comp.	10%	302-563
	R20	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R21	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R22	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
101 thru 13,343	R23	1 k	1/2 w	Fixed	Comp.	10%	302-102
13,344 & up	R23	680 Ω	1/2 w	Fixed	Comp.	10%	302-681
101 thru 13,343	R24	2.7 k	1/2 w	Fixed	Comp.	10%	302-272
13,344 & up	R24	1.5 k	1/2 w	Fixed	Comp.	10%	302-152

TYPE 545

Resistors Cont.

	R28	500 Ω	2 w	Var.	Comp.	20%	311-005
	R29	22 k	2 w	Fixed	Comp.	10%	306-223
	R30	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
	R32	820 Ω	1/2 w	Fixed	Comp.	10%	302-821
	R33	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R34	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R35	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R36	100 k	2 w	Var.	Comp.	20%	311-026
	R37	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R38	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R39	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R40	220 k	1/2 w	Fixed	Comp.	10%	302-224
	R41	10 k	1/2 w	Fixed	Comp.	10%	302-103
	R42	470 k	1/2 w	Fixed	Comp.	10%	302-474
101 thru 7400	*R43	100 k	1/2 w	Var.	Comp.	20%	311-030*
	*Note: R14 & R43 concentric (Instruments without Preset Stability)						
7401 & up*	**R43	100 k	1/2 w	Var.	Comp.	20%	311-096
	**Note: R43 concentric with R14 & SW43 (Instruments with Preset Stability)						
	R44	100 k	1/2 w	Fixed	Comp.	5%	301-104
	R45	200 k	1/2 w	Fixed	Comp.	5%	301-204
	R46	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R47	470 k	1/2 w	Fixed	Comp.	5%	301-474
	R48	47 k	1 w	Fixed	Comp.	10%	304-473
Added 5946 & up	R49	100 k	2 w	Var.	Comp.	20%	311-026
	R50	95 k	1/2 w	Fixed	Prec.	1%	309-044
	R51	220 k	1/2 w	Fixed	Prec.	1%	309-052
	R52	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R53	22 k	2 w	Fixed	Comp.	10%	306-223
	R54	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R55A	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
	R55B	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R57	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
	R58	1 k	1/2 w	Fixed	Comp.	10%	302-102
	R59	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R60	2.7 k	1 w	Fixed	Comp.	Selected*)	
	R61	3.3 k	1 w	Fixed	Comp.	Selected*)	312-569
*Note:	R60 & R61 selected to total 6 k, ±2 1/2%. Furnished as a unit.						
	R62	56 k	1 w	Fixed	Comp.	5%	303-563
	R63	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R64	2.5 k	1/10 w	Var.	Comp.	20%	311-010
	R65	39 k	1 w	Fixed	Comp	Selected*)	
	R66	33 k	1 w	Fixed	Comp.	Selected*)	312-570
	R67	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R68	8 k	5 w	Fixed	WW	5%	308-053
	R69	1 k	1/2 w	Fixed	Comp.	10%	302-102
	R70	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R71	270 Ω	1/2 w	Fixed	Comp.	10%	302-271
Added 5117 & up	R72	47 Ω	1/2 w	Fixed	Comp.	10%	302-470

Type 545

Resistors Cont.

	R73	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R74	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R75	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R76	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R77	4.7 k	1 w	Fixed	Comp.	10%	304-472
101 thru 9860	R78	47 k	1/2 w	Fixed	Comp.	10%	~~302-473~~ Use 301-363
9861 & up	R78	36 k	1/2 w	Fixed	Comp.	5%	301-363
	R79	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R80	10 k	1/2 w	Fixed	Comp.	10%	302-103
	R81	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R82	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R83	1.8 meg	1/2 w	Fixed	Comp.	10%	302-185
	R84	100 k	1 w	Fixed	Comp.	10%	304-104
	R85	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R86	470 Ω	1/2 w	Fixed	Comp.	10%	302-471
	R87	8 k	5 w	Fixed	WW	5%	308-053
	R88	2 k	2 w	Var.	Comp.	20%	311-008
	R89	4 k	5 w	Fixed	WW	5%	308-051
	R90	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R91	22 k	2 w	Fixed	Comp.	10%	306-223
	R92	22 k	2 w	Fixed	Comp.	10%	306-223
	R93	22 k	2 w	Fixed	Comp.	10%	306-223
	R95	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R96	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
101 thru 1303	R97	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
1304 & up	R97	Deleted					
	R99A	30 meg	2 w	Fixed	Prec.	1%	310-505
	R99B	10 meg	1 w	Fixed	Prec.	1%	310-107
	R99C	10 meg	1 w	Fixed	Prec.	1%	310-107
	R99D	3 meg	1/2 w	Fixed	Prec.	1%	309-026
	R99E	1 meg	1/2 w	Fixed	Prec.	1%	309-014
	R99F	1 meg	1/2 w	Fixed	Prec.	1%	309-014
	R99G	300 k	1/2 w	Fixed	Prec.	1%	309-125
	R99H	100 k	1/2 w	Fixed	Prec.	1%	309-045
	R99J	100 k	1/2 w	Fixed	Prec.	1%	309-045
101 thru 1683	R99K	10 k	1/2 w	Fixed	Comp.	10%	302-103
1684 & up	R99K	6.8 k	1 w	Fixed	Comp.	10%	304-682
101 thru 1683	R99L	20 k	2 w	Var.	Comp.	20%	311-018
1684 & up	R99L	15 k	2 w	Var.	Comp.	20%	311-045
101 thru 198	R99M	Selected for individual instrument.				USE	311-056
199 & up	R99M	500 Ω	1/10 w	Var.	Comp.	20%	311-056
	R101	900 k	1/2 w	Fixed	Prec.	1%	309-111
	R102	111 k	1/2 w	Fixed	Prec.	1%	309-046
	*R105	100 k	1/2 w	Var.	Comp.	20%	311-046
	R106	22 k	1/2 w	Fixed	Comp.	10%	302-223
	R107	1 meg	1/2 w	Fixed	Comp.	10%	302-105

*Note: R105, R122, and R140 furnished as a unit.

TYPE 545

Resistors Cont.

	R108	100 k	1/2 w	Fixed	Comp.	10%	302-104
Added 5646 & up	R109	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R110	1 meg	1/2 w	Fixed	Prec.	1%	309-014
101 thru 8299	R113	47 k	1 w	Fixed	Comp.	10%	304-473
8300 & up	R113	33 k	1 w	Fixed	Comp.	10%	304-333
	R114	50 k	2 w	Var.	Comp.	20%	311-023
	R115	47 k	1 w	Fixed	Comp.	10%	304-473
	R120	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R121	47 k	1 w	Fixed	Comp.	10%	304-473
	*R122	15 k	1/2 w	Fixed	Comp.	20%	311-046
	R123	47 k	1 w	Fixed	Comp.	10%	304-473
	R124	33 k	2 w	Fixed	Comp.	10%	306-333
	R130	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R131	3.3 k	1/2 w	Fixed	Comp.	10%	302-332
	R132	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R133	270 k	1/2 w	Fixed	Comp.	10%	302-274
	R134	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R135	33 k	2 w	Fixed	Comp.	10%	306-333
	R136	2.2 k	1/2 w	Fixed	Comp.	10%	302-222
	*R140	100 k	1/2 w	Var.	Comp.	20%	311-046

*Note: R105, R122, and R140 furnished as a unit.

	R141	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R142	27 k	1/2 w	Fixed	Comp.	10%	302-273
	R143	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R146	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R147	22 k	1 w	Fixed	Comp.	10%	304-223
	R148	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R150	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R151	1 k	1/2 w	Fixed	Comp.	10%	302-102
	R155	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R156	10 k	1 w	Fixed	Comp.	5%	303-103
	R157	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R158	39 k	1 w	Fixed	Comp.	5%	303-393
	R159	33 k	1 w	Fixed	Comp.	5%	303-333
	R160	15 k	2 w	Fixed	Comp.	5%	305-153
	R163	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R164	2.2 k	1/2 w	Fixed	Comp.	10%	302-222
	R165	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R170	2.7 k	1/2 w	Fixed	Comp.	10%	302-272
	R172	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R173	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R174	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R177	10 k	1/2 w	Fixed	Comp.	10%	302-103
	R180	15 k	2 w	Fixed	Comp.	10%	306-153
	R181A	10 k	2 w	Var.	Comp.	20%	311-016
	R181B		1/2 w	Fixed	Comp.	Sel. to center sw. length	

TYPE 545

Resistors Cont.

	R182A	12 k	2 w	Fixed	Comp.	10%		306-123
	R182B		1/2 w	Fixed	Comp.	Sel. to center sw. length		
	R185	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R186	220 k	2 w	Fixed	Comp.	10%		306-224
	R187	100 k	1/2 w	Fixed	Comp.	10%		302-104
	R188	1.5 meg	1/2 w	Fixed	Comp.	10%		302-155
	R190A	404 k	1/2 w	Fixed	Prec.	1/4%	selected	312-567
	R190B	606 k	1/2 w	Fixed	Prec.	1/4%	selected	312-568
	R190C	1.01 meg	1/2 w	Fixed	Prec.	1/4%	selected	312-571
	R195	100 k	2 w	Var.	Comp.	20%		311-026
	R196	470 k	1/2 w	Fixed	Comp.	10%		302-474
	R197	6.8 k	1/2 w	Fixed	Comp.	10%		302-682
	R198	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R200	100 k	1/2 w	Fixed	Comp.	10%		302-104
	R201	47 k	1/2 w	Fixed	Comp.	10%		302-473
	R202	10 k	1/2 w	Fixed	Comp.	10%		302-103
	R205	15 k	1/2 w	Fixed	Comp.	10%		302-153
	R206	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R207	10 k	5 w	Fixed	WW	5%		308-054
	R208	10 k	2 w	Var.	WW	20%		311-015
	R209	30 k	3 w	Var.	Helipot	.1%		311-022
	R216	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R217	3.9 k	1/2 w	Fixed	Comp.	10%		302-392
	R218	95 k	1/2 w	Fixed	Prec.	1%		309-044
	R219	150 k	1/2 w	Fixed	Prec.	1%		309-049
	R220	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R223	39 k	2 w	Fixed	Comp.	10%		306-393
101 thru 6026	R224	4.7 k	1/2 w	Fixed	Comp.	10%		302-472
6027 & up	R224	5.6 k	1/2 w	Fixed	Comp.	10%		302-562
	R228	10 k	1/2 w	Fixed	Comp.	10%		302-103
	R229	270 k	1/2 w	Fixed	Comp.	10%		302-274
	R230	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R231	1 k	1/2 w	Fixed	Comp.	10%		302-102
Added 5125 & up	R232	47 Ω	1/2 w	Fixed	Comp.	10%		302-470
	R235	22 k	1/2 w	Fixed	Comp.	10%		302-223
	R236	22 meg	1/2 w	Fixed	Comp.	10%		302-226
101 - 13,343	R240	1 meg	1/2 w	Fixed	Prec.	1%		309-014
13,344-14,222	R240	1.94 meg	1/2 w	Fixed	Prec.	1%		309-022
14,223 & up	R240	1.75 meg	1/2 w	Fixed	Prec.	1%		309-019
101 - 13,343	R241	1.23 meg	1/2 w	Fixed	Prec.	1%		309-016
13,344 & up	R241	3.1 meg	1/2 w	Fixed	Prec.	1%		309-027
	R242	100 Ω	1/2 w	Fixed	Comp.	10%		302-101
	R243	100 k	1 w	Fixed	Comp.	10%		304-104
	R244	2.2 k	1/2 w	Fixed	Comp.	10%		302-222

Changes made to Type 545 at SN 13,344 were made to RM45 at SN 306.

Changes made to Type 545 at SN 14,223 were made to RM45 at SN 419.

TYPE 545

Resistors Cont.

Changes made to Type 545 at SN 13,344 were made to RM45 at SN 306, R253 was deleted.

Changes made to Type 545 at SN 14,223 were made to RM45 at SN 419

Add 14,223 & up	R245	22 meg	1/2 w	Fixed	Comp.	10%	302-226
101 - 13,343	R246	470 k	1/2 w	Fixed	Comp.	10%	302-474
13,344 & up	R246	100 k	2 w	Var.	Comp.	20%	311-030
101 - 13,343	R247	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
13,344 & up	R247	9 meg	1/2 w	Fixed	Prec.	1%	309-232
101 - 13,343	R248	500 k	1/2 w	Var.	Comp.	20%	311-048*
13,344 & up	R248	100 k	Furnished with R246 (311-030)				
101 - 13,343	R249	560 k	1/2 w	Fixed	Comp.	10%	302-564
13,344 & up	R249	33 k	1/2 w	Fixed	Comp.	10%	302-333
101 - 13,343	R250	500 k	Furnished with R248 (311-048)				
13,344 - 14,222	R250	Deleted					
14,223 & up	R250	47 k	1/2 w	Fixed	Comp.	10%	302-473
101 - 13,343	R253	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R254	111 k	1/2 w	Fixed	Prec.	1%	309-046
	R255	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R256	100 k	1 w	Fixed	Comp.	10%	304-104
	R259	400 k	1 w	Fixed	Prec.	1%	310-094
	R260	400 k	1 w	Fixed	Prec.	1%	310-094
	R261	22 k	1/2 w	Fixed	Comp.	10%	302-223
	R262	20 k	2 w	Var.	Comp.	20%	311-018
	R265	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R266	10 k	2 w	Var.	Comp.	20%	311-016
	R267	2.2 k	1 w	Fixed	Comp.	10%	304-222
	R268	6 k	5 w	Fixed	WW	5%	308-052
	R269	2.2 k	1 w	Fixed	Comp.	10%	304-222
	R270	2 k	2 w	Var.	Comp.	20%	311-008
	R272	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R273	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R278	6-25 k	5 w	Fixed	Mica Plate		310-506
	R279	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R282	390 Ω	1/2 w	Fixed	Comp.	10%	302-391
	R283	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R284	2.2 k	1/2 w	Fixed	Comp.	10%	302-222
	R286	6-30 k	5 w	Fixed	Mica Plate		310-507
	R287	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R288	39 k	2 w	Fixed	Comp.	10%	306-393
	R289	39 k	2 w	Fixed	Comp.	10%	306-393
	R292	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R293	470 k	1/2 w	Fixed	Comp.	10%	302-474
101 thru 9406	R294	470 k	1/2 w	Fixed	Comp	10%	302-474
407 & up	R294	820 k	1/2 w	Fixed	Comp.	10%	302-824

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Resistors Cont.

_01 thru 9406	R295	470 k	1/2 w	Fixed	Comp.	10%	302-474
9407 & up	R295	820 k	1/2 w	Fixed	Comp.	10%	302-824
	R670	150 k	1/2 w	Fixed	Comp.	10%	302-154
	R671	1 k	1/2 w	Fixed	Comp.	10%	302-102
101 thru 13, 343	R672	3.3 meg	1/2 w	Fixed	Comp.	10%	302-335
13,344 and up	R672	3.9 meg	1/2 w	Fixed	Comp.	10%	302-395
	R673	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
	R674	1 k	1/2 w	Fixed	Comp.	10%	302-102
	R675	68 k	1/2 w	Fixed	Comp.	10%	302-683
	R676	33 k	1 w	Fixed	Comp.	10%	304-333
	R679	10 k	2 w	Var.	Comp.	20%	311-016
101 thru 13,821		100 k	1/2 w	Fixed	Comp.	10%	302-104
13,822 & up	R680	68 k	1/2 w	Fixed	Comp.	10%	302-683
	R681	1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
	R682	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R683	9.5 k	1/2 w	Fixed	Prec.	1%	309-121
	R684	6.375 k	1/2 w	Fixed	Prec.	1%	309-119
	R685	2.1 k	1/2 w	Fixed	Prec.	1%	309-117
	R686	1.025 k	1/2 w	Fixed	Prec.	1%	309-116
	R687	610 Ω	1/2 w	Fixed	Prec.	1%	309-113
	R688	200 Ω	1/2 w	Fixed	Prec.	1%	309-073
	R689	100 Ω	1/2 w	Fixed	Prec.	1%	309-112
	R690	60 Ω	1/2 w	Fixed	Prec.	1%	309-067
	R691	40 Ω	1/2 w	Fixed	Prec.	1%	309-066
	R694	100 k	1/2 w	Fixed	Prec.	1%	309-045
	R695	100 Ω	1/2 w	Fixed	Prec.	1%	309-112
Added 5001 & up	R698	1/4 Ω	1/2 w	Fixed	WW	10%	308-090
	R699	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R700	15 k	1 w	Fixed	Comp.	10%	304-153
	R701	15 k	1 w	Fixed	Comp.	10%	304-153
	R703	68 k	1/2 w	Fixed	Comp.	10%	302-683
	R704	27 k	1/2 w	Fixed	Comp.	10%	302-273
	R706	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
	R707	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
	R708	12 Ω	1 w	Fixed	Comp.	10%	304-120
	R710	33 k	1/2 w	Fixed	Comp.	10%	302-333
	R711	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R712	100 k	1/2 w	Fixed	Comp.	10%	302-104
Added 401 & up	R713	1 k	1/2 w	Fixed	Comp.	10%	302-102
101 thru 1186	R715	50 k	1/2 w	Fixed	Prec.	~~309-090~~ USE	310-086
1187 & up	R715	50 k	1 w	Fixed	Prec.	1%	310-086
	R716	10 k	2 w	Var.	WW	20%	311-015
	R717	100 k	1/2 w	Fixed	Comp.	10%	302-104
101 thru 1186	R718	68 k	1/2 w	Fixed	Prec.	~~309-053~~ USE	310-054
187 & up	R718	68 k	1 w	Fixed	Prec.	1%	310-054
	R719	470 k	1/2 w	Fixed	Comp.	10%	302-474
Added 5448 & up	R720	10 Ω	1/2 w	Fixed	Comp.	10%	302-100

Resistors Cont.

Added 221 & up	*R724	1 k	25 w	Fixed	WW	5%		308-037
101 thru 220	*R725	1 k	25 w	Fixed	WW	5%		308-037
221 thru 5367	R725	Deleted. (Became R724)						
5368 & up	R725	10 k	2 w	Fixed	Comp.	10%		306-103

*Note: Manuals did not include a resistor shunting R725 (changed to R724 at SN 221). This resistor is a 10k, 2w, Fixed, Comp., 10%, 306-103.

	R726	1 k	1/2 w	Fixed	Comp.	10%		302-102
	R727	1 k	1/2 w	"	"	"		302-102
	R728	150 k	1/2 w	"	"	"		302-154
	R729	1 meg	1/2 w	"	"	"		302-105
Added 9839 & up	R730	100 Ω	1/2 w	"	"	"		302-101
101 thru 5367	R732	10 Ω/2	1 w	"	"	"	(2)	304-100
5368 & up	R732	10 Ω	1 w	"	"	"		304-100
Added 5368 & up	R733	10 Ω	1 w	"	"	"		304-100
	R735	100 k	1/2 w	"	"	"		302-104
	R736	50 Ω	2 w	Var.	WW	20%		311-055
	R740	10 Ω	1 w	Fixed	Comp.	10%		304-100
	R742	47 k	1/2 w	"	"	"		302-473
	R743	39 k	1/2 w	"	"	"		302-393
	R744	680 k	1/2 w	"	"	"		302-684
	R747	1.5 meg	1/2 w	"	"	"		302-155
	R748	30 k	10 w	"	WW	5%		308-027
	R749	750 Ω	10 w	"	WW	5%		308-016
101-thru 1505	R750	333 k	1/2 w	"	Prec.	~~309-051~~	USE	310-056
1506 & up	R750	333 k	1 w	"	"	1%		310-056
101 thru 1505	R751	490 k	1/2 w	"	"	~~309-002~~	USE	310-057
1506 & up	R751	490 k	1 w	"	"	1%		310-057
	R756	10 Ω	2 w	"	Comp.	10%		306-100
	R757	270 k	1/2 w	"	"	"		302-274
	R758	56 k	1/2 w	"	"	"		302-563
	R760	1.5 meg	1/2 w	"	"	"		302-155
	*R762	2 k	10 w	"	WW	5%		308-017
	R763	1.5 meg	1/2 w	"	Comp.	10%		302-155
	R764	2.2 meg	1/2 w	"	"	"		302-225
	R765	180 k	1/2 w	"	"	"		302-184

*Note: SN's 101 thru 220--this was called R761.

	R766	82 k	1 w	"	"	"		304-823
Added 401 & up	R767	1 k	1/2 w	"	"	"		302-102
	R770	2.2 meg	1/2 w	"	"	"		302-225
101 thru 1505	R771	220 k	1/2 w	"	Prec.	~~309-052~~	USE	310-055
1506 & up	R771	220 k	1 w	"	"	1%		310-055

Resistors Cont.

101 thru 1505	R772	333 k	1/2 w	Fixed	Prec.	~~309-053~~	USE	310-056
1506 & up	R772	333 k	1 w	"	"	1%		310-056
Added 5368 & up	R777	10 Ω	1 w	"	Comp.	10%		304-100
	R778	82 k	2 w	"	"	"		306-823
	R779	2.2 meg	1/2 w	"	"	"		302-225
101 thru 5367	R780	10 Ω/2	1 w	"	"	"	(2)	304-100
5368 & up	R780	10 Ω	1 w	"	"	"		304-100
101 thru 9291	R781	1.5 meg	1/2 w	"	"	"		302-155
9292 & up	R781	1 meg	1/2 w	"	"	"		302-105
101 thru 9291	R782	390 k	1/2 w	"	"	"		302-394
9292 & up	R782	560 k	1/2 w	"	"	"		302-564
	R783	47 k	1/2 w	"	"	"		302-473
	R784	1.5 meg	1/2 w	"	"	"		302-155
Add 221 thru 5367	R785	2 k/2	20 w	"	WW	5%	(2)	308-031
5368 thru 9291	R785	2 k	20 w	"	"	"		308-031
9292 & up	R785	1.5 k	25 w	"	"	"		308-040
101 thru 220	R786	2 k/2	20 w	"	"	"		308-031
221 thru 5367	R786	Deleted						
5368 thru 9291	R786	2 k	20 w	"	"	"		308-031
9292 & up	R786	1.5 k	25 w	"	"	"		308-040
101 thru 1505	*R787	1.84 meg	1/2 w	"	Prec.	~~309-021~~	USE	308-083
1506 & up	R787	236 k	1 w	"	WW	1%		308-083
101 thru 1505	*R788	780 k	1/2 w	"	Prec.	~~309-011~~	USE	308-084
1506 & up	R788	100 k	1/2 w	"	WW	1%		308-084
*Note:	Replace both at the same time with new Tek. Nos.							
	R789	1 k	1/2 w	"	Comp.	10%		302-102
	R790	10 Ω	1/2 w	"	"	"		302-100
	R791	150 k	1/2 w	"	"	"		302-154
	R792	120 k	1/2 w	"	"	"		302-124
	R793	27 k	1/2 w	"	"	"		302-273
	R794	1 meg	1/2 w	"	"	"		302-105
	*R795	3 k	10 w	"	WW	5%		308-020
101 thru 1505	R797	220 k	1/2 w	"	Prec.	~~309-052~~	USE	310-055
1506 & up	R797	220 k	1 w	"	"	1%		310-055
101 thru 1505	R798	720 k	1/2 w	"	"	~~309-009~~	USE	310-059
1506 & up	R798	720 k	1 w	"	"	1%		310-059
*Note:	SN's 101 thru 220, this was called R796.							
	R800	1 k	1/2 w	Fixed	Comp.	10%		302-102
	R803	56 k	2 w	"	"	"		306-563
	R804	100 k	1/2 w	"	"	"		302-104
	R805	1 k	1/2 w	"	"	"		302-102
	R807	390 Ω	2 w	"	"	"		306-391

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Resistors Cont.

	R810	470 k	1/2 w	Fixed	Comp.	10%	302-474
	R811	2 meg	2 w	Var.	Comp.	20%	311-042
	R812	2.2 meg	1/2 w	Fixed	Comp.	10%	302-225
	R813	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
	R814	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
	R815	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
	R830	47 k	1/2 w	Fixed	Comp.	10%	302-473
	R831	1 meg	2 w	Var.	Comp.	20%	311-041
	R832	4.7 meg	2 w	Fixed	Comp.	10%	306-475
	R833	4.7 meg	2 w	Fixed	Comp.	10%	306-475
	R834	100 k	1/2 w	Fixed	Comp.	10%	302-104
	R835	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R837	4.7 meg	1/2 w	Fixed	Comp.	10%	302-475
	R838	1 k	1/2 w	Fixed	Comp.	10%	302-102
	R839	100 Ω	1/2 w	Fixed	Comp.	10%	302-101
	R840	68 k	2 w	Fixed	Comp.	10%	306-683
	R841	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
	R850	2.2 meg	2 w	Fixed	Comp.	10%	306-225
	R851	2.2 meg	2 w	Fixed	Comp.	10%	306-225
	R852	2 meg	2 w	Var.	Comp.	20%	311-043
	R853	1 meg	2 w	Fixed	Comp.	10%	306-105
	R855	10 k	1/2 w	Fixed	Comp.	10%	302-103
	R856	27 k	1/2 w	Fixed	Comp.	10%	302-273
	R857	1 meg	1/2 w	Fixed	Comp.	10%	302-105
	R860	50 k	2 w	Var.	Comp.	20%	311-023
	R861	100 k	2 w	Var.	Comp.	20%	311-026
	R863	100 k	1/2 w	Fixed	Comp.	10%	302-104
	**R864	150 k	1/2 w	Fixed	Comp.	10%	302-154
**Note:	Nominal value, may vary between instruments.						
Add 9292 & up	R1003	100 Ω	1 w	Fixed	Comp.	10%	304-101
Add 9292 & up	R1005	100 Ω	1 w	Fixed	Comp.	10%	304-101
Add 9292 & up	R1007	47 Ω	½ w	Fixed	Comp.	10%	302-470
Add 9292 & up	R1008	47 Ω	½ w	Fixed	Comp.	10%	302-470
Add 9292 & up	R1009	100 Ω	1 w	Fixed	Comp.	10%	304-101
101 thru 9291	*R1010	1 meg	½ w	Fixed	Comp.	10%	302-105
101 thru 5805	R1011	1 meg	½ w	Fixed	Comp.	10%	302-105
5806 thru 9291	R1011	100 k	½ w	Fixed	Comp.	10%	302-104
9292 & up	R1011	27 Ω	¼ w	Fixed	Comp.	10%	302-270
101 thru 9291	*R1012	470 k	½ w	Fixed	Comp.	10%	302-474
Note:	*Circuit numbers DELETED - SN 9292 and up.						
101 thru 5805	R1013	1 meg	½ w	Fixed	Comp.	10%	302-105
806 thru 9291	R1013	100 k	½ w	Fixed	Comp.	10%	302-104
9292 & up	R1013	910 Ω	2 w	Fixed	Comp.	5%	305-911
101 thru 9291	R1014	1 meg	½ w	Fixed	Comp.	10%	302-105
9292 & up	R1014	500 Ω	½ w	Mica plate		2%	310-515

Resistors Cont.

101 - 9291	R1015	1 k	½ w	Fixed	Comp.	10%	302-102
9292 & up	R1015	150 k	½ w	"	"	"	302-154
Added 9292-11,691	R1016	4 k	5 w	"	WW	5%	308-051
11,692 & up	R1016	3 k	5 w	"	WW	5%	308-062
Added 9292-11,691	R1017	12 k	8 w	"	WW	5%	308-069
11,692 & up	R1017	10 k	8 w	"	WW	5%	308-126
Added 9292 & up	R1018	330 Ω	½ w	Fixed	Comp.	10%	302-331
Added 9292 & up	R1019	470 k	½ w	"	"	"	302-474
101 - 8667	R1020	1.2 k	2 w	"	"	"	306-122
8668 - 9291	*R1020	1.2 k	2 w	"	"	5%	305-122
101 - 9291	R1021	650 Ω	½ w	"	Mica Plate		310-513
9292 & up	R1021	27 Ω	½ w	"	Comp.	10%	302-270
101 - 9291	*R1022	100 Ω	½ w	Fixed	Comp.	10%	302-101
101 - 9291	*R1023	68 k	1/10 w	"	"	"	307-006
Added 9292 & up	R1024	500 Ω	½ w	"	Mica Plate		310-515
101 - 9291	*R1025	27 Ω	½ w	"	Comp.	10%	302-270
	R1026	330 Ω	½ w	"	"	"	302-331
	R1027	200 Ω	2 w	Var.	Comp.		311-004
101 - 9291	*R1028	330 Ω	½ w	Fixed	"	10%	302-331
Added 9292 & up	R1029	470 k	½ w	"	"	"	302-474
101 - 9291	R1030	4 k	5 w	"	WW	5%	308-051
101 - 9291	R1031	15 k	10 w	"	WW	5%	308-024
9292 - 11,691	R1031	4.7 k	1 w	Fixed	Comp.	10%	304-472
11,692 & up	R1031	2.2 k	1 w	"	"	"	304-222
Added 9292-11,904	R1033	1.5 k	5 w	"	WW	5%	308-061
11,905 & up	R1033	2.5 k	5 w	"	WW	5%	308-127
101 - 9291	*R1035	10 k	1 w	"	Comp.	10%	304-103
Added 9292 & up	R1036	27 k	2 w	Fixed	Comp.	10%	306-273
Added 9292-11,904	R1039	39 Ω	½ w	"	"	"	302-390
11,905 & up	R1039	33 Ω	½ w	"	"	"	302-330
101 - 9291	*R1040	27 Ω	½ w	"	"	"	302-270
101 - 9291	*R1041	100 Ω	½ w	"	"	"	302-101
101 - 9291	*R1042	650 Ω	½ w	Fixed	Mica Plate		310-513
101 - 9291	*R1043	68 k	1/10 w	"	Comp.	10%	307-006
101 - 9291	*R1045	47 k	½ w	"	"	"	302-473
101 - 9291	R1046	100 Ω	½ w	"	"	"	302-101
9292 & up	R1046	27 k	2 w	"	"	"	306-273
101 - 9291	*R1047	100 Ω	½ w	Fixed	Comp.	10%	302-101
Added 9292-11,904	R1049	39 Ω	½ w	"	"	"	302-390
11,905 & up	R1049	33 Ω	½ w	"	"	"	302-330
101 - 9291	*R1050	47 k	½ w	"	"	"	302-473
101 - 9291	*R1051	2.2 k	1 w	"	"	"	304-222
101 - 9291	R1052	47 Ω	½ w	Fixed	"	"	302-470
9292 & up	R1052	470 k	½ w	"	"	"	302-474
101 - 9291	*R1053	30 k	10 w	"	WW	5%	308-027
101 - 9291	R1054	47 Ω	½ w	"	Comp,	10%	302-470
9292 & up	R1054	167 Ω	5 w	"	WW	5%	308-104

Changes made to Type 545 at SN 11,692 were made to RM 45 at SN 206.
Changes made to Type 545 at SN 11,905 were made to RM 45 at SN 209.

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101 thru 9291	R1055	15 k	2 w	Fixed	Comp.	10%	306-153
9292 & up	R1055	4.5 k	5 w	Fixed	WW	5%	308-066
101 thru 9291	*R1056	1 meg	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-105
101 thru 9291	*R1057	2.7 k	2 w	Fixed	Comp.	10%	306-272
101 thru 9291	*R1059	250 k	2 w	Var.	Comp.	20%	311-061
101 thru 9291	*R1060	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
101 thru 9291	R1062	4.5 k	5 w	Fixed	WW	5%	308-066
9292 & up	R1062	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
101 thru 9291	R1064	167 Ω	5 w	Fixed	WW	5%	308-045
9292 - 14,733	R1064	2 k	1 w	Fixed	Comp.	5%	303-202
14,734 & up	R1064	Deleted	RM45,	SN 459			
101 thru 9291	*R1066	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
101 thru 210	R1067	2.2 k	1 w	Fixed	Comp.	~~304-222~~ USE	303-202
211 thru 9291	*R1067	2 k	1 w	Fixed	Comp.	5%	303-202
Add 9292-9719	R1071	600 Ω	5 w	Mica plate		~~310-541~~) USE	312-587
Add 9292-9719	R1073	600 Ω	5 w	Mica plate		~~310-541~~)	
9720 & up	R1071	600 Ω	5 w	Mica plate		)	312-587
9720 & up	R1073	600 Ω	5 w	Mica plate		)	
Add 9292 & up	R1075	220 Ω	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-221
Add 9292 & up	R1077	47 Ω	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-470
Add 9292 & up	R1078	150 Ω	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-151
101 thru 9291	R1080	8.2 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-822
9292 & up	R1080	150 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-154
101 thru 9291	R1081	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
9292 & up	R1081	330 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-334
101 thru 9291	*R1082	4.5 k	5 w	Fixed	WW	5%	308-066
101 thru 9291	R1083	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
9292 " 10,247	R1083	330 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-334
10,248 & up	R1083	390 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-394
101 thru 9291	R1084	8.2 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-822
9292 & up	R1084	680 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-684
Add 9292 & up	R1085	1 meg	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-105
Add 9292-10,247	R1087	330 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-334
10,248 & up	R1087	390 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-394
Add 9292 & up	R1089	1 meg	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-105
101 thru 9291	R1090	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
9292 & up	R1090	8.2 k	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-822
101 thru 9291	R1091	4.5 k	5 w	Fixed	WW	5%	308-066
9292 & up	R1091	250 k	2 w	Var.	Comp.		311-061
101 thru 9291	R1092	470 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-474
9292 & up	R1092	47 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-473
Add 9292-9596	R1093	15 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-153
9597 & up	R1093	deleted	(several instruments modified out of sequence)				
Add 9292 & up	R1094	68 k	.1 w	Fixed	Comp.	10%	307-006
Add 9292 & up	R1095	8.2 k	$\frac{1}{4}$ w	Fixed	Comp.	10%	316-822
Add 9292 & up	R1097	47 k	$\frac{1}{2}$ w	Fixed	Comp.	10%	302-473

Note: *Circuit numbers DELETED - SN 9292 and up.

TYPE 545

Resistors Cont.

Add 9292-9596	R1098	15 k	½ w	Fixed	Comp.	10%	302-153
9597 & up	R1098	deleted	(several instruments modified out of sequence)				
Add 9292 & up	R1099	68 k	1/10 w	Fixed	Comp.	10%	307-006
101 thru 9291	*R1100	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1101	4.5 k	5 w	Fixed	WW	5%	308-066
	R1102	470 k	½ w	Fixed	Comp.	10%	302-474
Add 9292 & up	R1105	4.5 k	5 w	Fixed	WW	5%	308-066
101 thru 9291	*R1110	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1111	4.5 k	5 w	Fixed	WW	5%	308-066
	R1112	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1120	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1121	4.5 k	5 w	Fixed	WW	5%	308-066
	R1122	470 k	½ w	Fixed	Comp.	10%	302-474
Add 9292 & up	R1125	4.5 k	5 w	Fixed	WW	5%	308-066
101 thru 9291	*R1130	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1131	4.5 k	5 w	Fixed	WW	5%	308-066
	R1132	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1140	390 Ω	½ w	Fixed	Comp.	5%	301-391
101 thru 266	R1141	10 k	5 w	Fixed	WW	5%	308-008
	in series with	1.8 k	1 w	Fixed	Comp.	10%	304-182
267 thru 9291	*R1141	12 k	8 w	Fixed	WW	5%	308-069
101 thru 8667	R1142	1.2 k	5 w	Fixed	WW	5%	308-063
8668 thru 9291	R1142	1.0 k	5 w	Fixed	WW	5%	308-106
9292 & up	R1142	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1143	390 Ω	½ w	Fixed	Comp.	5%	301-391
Add 9292 & up	R1145	4.5 k	5 w	Fixed	WW	5%	308-066
101 thru 9291	*R1150	100 Ω	1 w	Fixed	Comp.	10%	304-101
101 thru 9291	*R1151	100 Ω	1 w	Fixed	Comp.	10%	304-101
101 thru 9291	R1152	47 Ω	½ w	Fixed	Comp.	10%	302-470
9292 & up	R1152	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9291	*R1153	47 Ω	½ w	Fixed	Comp.	10%	302-470
101 thru 9291	*R1154	100 Ω	1 w	Fixed	Comp.	10%	304-101
	**R1155	150 k	½ w	Fixed	Comp.	10%	302-154
	**Note:	Called R1156 in some Manuals.					
Add 9292 & up	R1162	470 k	½ w	Fixed	Comp.	10%	302-474
Add 9292 & up	R1165	4.5 k	5 w	Fixed	WW	5%	308-066
Add 9292 & up	R1172	470 k	½ w	Fixed	Comp.	10%	302-474
Add 9292 & up	R1182	470 k	½ w	Fixed	Comp.	10%	302-474
Add 9292 & up	R1185	4.5 k	5 w	Fixed	WW	5%	308-066
Add 9292 & up	R1192	470 k	½ w	Fixed	Comp.	10%	302-474
101 thru 9117	R1201	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	*R1201	1 k	½ w	Fixed	Comp.	10%	302-102
101 thru 9117	R1202	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	R1202	1 k	½ w	Fixed	Comp.	10%	302-102
9292 & up	R1202	470 k	½ w	Fixed	Comp.	10%	302-474

Note: *Circuit numbers DELETED - SN9292 & up.

TYPE 545

Resistors Cont.

101 thru 9117	R1203	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	*R1203	1 k	½ w	Fixed	Comp.	10%	302-102
101 thru 9117	R1204	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	*R1204	1 k	½ w	Fixed	Comp.	10%	302-102
101 thru 9117	R1205	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	R1205	1 k	½ w	Fixed	Comp.	10%	302-102
9292 & up	R1205	4.5 k	5 w	Fixed	WW	5%	308-066
101 thru 9117	R1206	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	R1206	1 k	½ w	Fixed	Comp.	10%	302-102
9292 & up	R1206	360 Ω	½ w	Fixed	Comp.	5%	301-361
101 thru 9117	R1207	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	*R1207	1 k	½ w	Fixed	Comp.	10%	302-102
101 thru 9117	R1208	680 Ω	½ w	Fixed	Comp.	10%	302-681
9118 thru 9291	R1208	1 k	½ w	Fixed	Comp.	10%	302-102
9292 & up	R1208	12 k	8 w	Fixed	WW	5%	308-069
Add 9292 & up	R1212	470 k	½ w	Fixed	Comp.	10%	302-474
Add 9292 & up	R1216	360 Ω	½ w	Fixed	Comp.	5%	301-361
Add 9292 & up	R1218	1 k	5 w	Fixed	WW	5%	308-106
Add 9292 & up	R1221	100 Ω	½ w	Fixed	Comp.	10%	302-101
Add 9292-11,904	R1223	2.7 k	2 w	Fixed	Comp.	10%	306-272
11,905 & up M45, SN 209	R1223	4.7 k	2 w	Fixed	Comp.	10%	306-472
Add 9292 & up	R1224	30 k	10 w	Fixed	WW	5%	308-027
Add 9292 & up	R1226	100 Ω	½ w	Fixed	Comp.	10%	302-101
Add 9292 & up	R1227	15 k	2 w	Fixed	Comp.	10%	306-153
Add 9292 & up	R1228	1 meg	½ w	Fixed	Comp.	10%	302-105
Add 9292 & up	R1301-1308	1 k	½ w	Fixed	Comp.	10%	302-102

Note: *Circuit numbers DELETED - SN 9292 and up.

Fuses

F701	6 amp	3 AG	Fast-Blo	117 v	60 cycle	159-013
F701	3 amp	3 AG	Slo-Blo	234 v	50 cycle	159-005
*F730	No. 33 copper wire, coiled			~~195-000~~	USE	302-101

* Deleted SN9839 & up

TYPE 545

Neon Bulbs

"B" Circuit Nos. formerly designated as "NE".

101 thru 7754	B42	65-75 ignition	1/25 w	(Sweep Gen.) ~~150-014~~ USE	150-002
7755 & up	B42	50-75 v	1/25 w	(Sweep Generator)	150-002
101 thru 7754	B95	55 v drop	1/25 w	(Sweep Generator)	150-009
7755 & up	B95	50-75 v	1/25 w	(Sweep Generator)	150-002
101 thru 7754	B96	65 v drop	1/25 w	(Sweep Generator)	150-011
7755 & up	B96	50-75 v	1/25 w	(Sweep Generator)	150-002
101 thru 7754	B180	65 v drop	1/25 w	(Delaying Sweep Generator)	150-011
7755 & up	B180	50-75 v	1/25 w	(Delaying Sweep Generator)	150-002
101 thru 7754	B187	55 v drop	1/25 w	(Delaying Sweep Generator)	150-009
7755 & up	B187	50-75 v	1/25 w	(Delaying Sweep Generator)	150-002
101 thru 7754	B287	55 v drop	1/25 w	(Sweep Amp.) ~~150-009~~ USE	150-002
7755 & up	B287	50-75 v	1/25 w	(Sweep Amplifier)	150-002
101 thru 9291	B292	65-75 v ignition	1/25 w	Hor. Beam Position Ind.	150-014
9292 & up	B292	50-75 v	1/25 w	Hor. Beam Position Ind.	150-002
101 thru 9291	B293	65-75 v ignition	1/25 w	Hor. Beam Position Ind.	150-014
9292 & up	B293	50-75v	1/25 w	Hor. Beam Position Ind.	150-002
101 thru 1371	B1010	Vertical Beam Pos. Ind.		~~150-014~~ USE	150-002
1372 thru 9291	*B1010	Vertical Beam Pos. Ind.			150-002
101 thru 1371	B1014	Vertical Beam Pos. Ind.		~~150-014~~ USE	150-002
1371 thru 9291	*B1014	Vertical Beam Pos. Ind.			150-002
Add 9292 & up	B1083	Neon, Type NE-2			150-002
Add 9292 & up	B1087	Neon, Type NE-2			150-002

Incandescent Bulbs

	B730	#47	(Power Supply)	150-001
	B731	#47	(Power Supply)	150-001
	B732	#47	(Power Supply)	150-001

Inductors

	L61	88 µh	Fixed		108-022
	LR72	#40 wire, 450 turns, on 3.3 k, 1 w resistor			108-058
Add 9292-11,904	L1014	1.7-3.7 µh	Var.		114-088
11,905 & up	L1014	1.8-3.9 µh	Var.		114-112
101 thru 9291	*L1021	.3-.5 µh	Var.		114-037
101 thru 210	LR1022	2.5 µh	on 4.7 k ½ w 10% comp.	~~108-087~~ USE	108-103
211 thru 312	L1022	3.2 µh	Fixed	~~108-088~~ USE	108-103
313 thru 8397	L1022	2.5 µh	Fixed		108-103
8398 thru 9291	*L1022	1.8-3.7 µh	Var.		114-079
Add 9292-11,904	L1024	1.7-3.7 µh	Var.		114-088
11,905 & up	L1024	1.8-3.9 µh	Var.		114-112
Add 9292-11,904	L1036	.5-1 µh	Var.		114-087
11,905 & up	L1036	.5-.55 µh	Var.		114-111
101 thru 210	LR1041	2.5 µh	on 4.7 k ½ w 10% comp.	~~108-087~~ USE	108-103
211 thru 312	L1041	3.2 µh	Fixed	~~108-088~~ USE	108-103

Changes made to Type 545 at SN 11,905 were made to RM45 at SN 209.

Note: *Circuit numbers DELETED - SN 9292 and up.

Inductors Cont.

All changes made to Type 545 at SN 10,120 were made to RM45 at SN 172.

313 thru 8397	L1041	2.5 μh	Fixed		108-103
8398 thru 9291	*L1041	1.8-3.7 μh	Var.		114-079
101 thru 9291	*L1042	.3-.5 μh	Var.		114-037
Add 9292-11,904	L1046	.5-1 μh	Var.		114-087
11,905 & up	L1046	.5-.55 μh	Var.		114-111
RM45, SN 209					
Add 9292-14,733	L1064	14 μh	Fixed		108-134
14,734 & up	L1064	8.4 μh	Fixed		108-157
101 thru 9291	*L1067	12 μh	Fixed		108-005
101 thru 9291	*L1070		Terminating Line		108-081
101 thru 9291	L1071		Terminating Line		108-081
9292-10119	L1071	.9-1.6 μh	Var.		114-038
10120 & up	L1071	.3-.5 μh	Var.		114-092
Add 9292-10119	L1073	.9-1.6 μh	Var.		114-038
10120 & up	L1073	.3-.5 μh	Var.		114-092
101 thru 9291	*L1080		Plate Line		108-096
101 thru 9291	*L1081		Grid Line		108-080
101 thru 9291	*L1082		Grid Line		108-080
101 thru 9291	*L1083		Plate Line		108-096
Add 9292-10119	L1103		Grid Line	~~108-136~~ USE	108-145
10120 & up	L1103		Grid Line		108-145
Add 9292-10119	L1104		Plate Line		108-135
10120 & up	L1104		Plate Line		108-139
Add 9292-10119	L1113		Grid Line	~~108-136~~ USE	108-145
10120 & up	L1113		Grid Line		108-145
Add 9292-10119	L1114		Plate Line		108-135
10120 & up	L1114		Plate Line		108-139
101 thru 9117	L1204		Delay Line, 30 section		108-094
9118 thru 9291	*L1204		Delay Line, 30 section		108-133
101 thru 9117	L1205		Delay Line, 30 section		108-094
9118 thru 9291	*L1205		Delay Line, 30 section		108-133
101 thru 9117	L1234		Delay Line, 20 section		108-093
9118 thru 9291	*L1234		Delay Line, 20 section		108-132
101 thru 9117	L1235		Delay Line, 20 section		108-093
9118 thru 9291	*L1235		Delay Line, 20 section		108-132
101 thru 9291	*L1254	0.9-1.6 μh	Var.		114-038
101 thru 9291	*L1255	0.9-1.6 μh	Var.		114-038
Add 9292 & up	L1304		Delay Line, 30 section		108-133
Add 9292 & up	L1305		Delay Line, 30 section		108-133
Add 9292 & up	L1334		Delay Line, 20 section		108-132
Add 9292 & up	L1335		Delay Line, 20 section		108-132
Add 9292 & up	L1354	0.9-1.6 μh	Var.		114-038
Add 9292 & up	L1355	0.9-1.6 μh	Var.		114-038

Note: *Circuit numbers DELETED - SN 9292 and up.

TYPE 545

Knobs

	Old Type 101 thru 1051 Except*	New Type 1052 & up Plus*
Knob, red, white dot, for 1/8" shaft Used: Trig.Mode; Length (Delaying Sweep); 5X Magnifier; Multiplier; Sq. Wave Calibrator. (5)	366-017	366-038
Knob, red, white dot, for 3/16" shaft Used: Stability (Main Sweep); Vernier; Stability (Delaying Sweep). (3)	366-018	366-039
Knob, black, flanged, coaxial type, 1/4" center hole Used: Trig. Slope; Time/CM (Main Sweep); Time/CM (Delaying Sweep); Multiplier; Sq. Wave Cal. (5)	366-021	366-040
Knob, black, flanged Used: Horizontal Display. (1)	366-020	366-042
Knob, black, white dot Used: Scale Illum; Astigmatism; Intensity; Focus (4)	366-019 S/N 6151 & up	366-044 366-033
Knob, black, flanged, coaxial type, 17/64" center hole Used: Triggering Level (Del. Sweep); Triggering Level (Main Sweep); Horizontal Position. (3)	366-022	366-046
Knob, red, Preset engraved Used: Stability (Main Sweep) Preset stability mod kits		366-064

For CM of Delay of Delay Time Multiplier see Dial, Miscellaneous.

*New knobs used on SN's 1025 thru 1028. The new knobs are basically the same as the old type except for a slight change in appearance; color is the same. All knobs will be replaced by the new type knob unless specifically requested by the customer to supply the old type.

Selenium Rectifiers

SR732	5-250 ma plates per leg	106-012
SR740	5-500 ma plates per leg	106-013
SR756	4-500 ma plates per leg	106-019
SR780	4-250 ma plates per leg	106-014
SR790	5-125 ma plates per leg	106-015

Relays

K700	45-sec.	Thermal Time-delay	Amperite 6N045T	148-002
K701	Relay	4P2T	6 volt	148-004

Switches

All changes made to Type 545 at SN 13,344 were made to RM45 at SN 306.

			not wired	wired
101 thru 13,343	SW1 & SW5	Trigger Slope & Mode	260-099	262-080
13,344 & up	SW1 & SW5	Trigger Slope & Mode	260-099	262-183
Added 7401 & up	SW43 concentric with R14 & R43		311-096	
	*SW55	Time/CM	260-010	262-063
	SW90	Multiplier	260-011	262-064
	SW100	Atten	260-014	---
	SW113	Slope	260-014	---
	SW190	Time/CM	260-009	262-060
	SW200	Horizontal	260-007	262-061
	SW235	Reset, Main Sweep	260-017	
	*SW254	5X Magnifier	260-010	262-063

*Note: SW254 and SW55 are concentric. Furnished as a unit.

			not wired	wired
101 thru 8266	*SW670	Volts, Millivolts, Off)	USE	262-132
101 thru 8266	*SW680	Square Wave Calibrator)	~~260-013~~	~~262-065~~
8267 & up	*SW670	Volts, Millivolts, Off)		
8267 & up	*SW680	Square Wave Calibrator)	260-177	262-132
	SW701	Power On		260-134

*Note: SW670 and SW680 Shafts are concentric. Furnished as a unit.

Thermal Cut-Out

TK701	Thermal Cut-out, Type SE11	128°	260-070

Transformers

	T700	Plate and Heater Supply (Power)	120-037
Export, All SNs	T700	Plate & Heater Supply (Power)	120-086
	T801	CRT Supply	120-036

Vacuum Tubes

All changes made to Type 545 at SN 13,344 were made to RM45 at SN306.

101 - 13,343	V8	6BQ7A	Trigger Amplifier	154-028
13,344 & up	V8	6DJ8	Trigger Amplifier	154-187
101 - 13,343	V20	6U8	Trigger Shaper	154-033
13,344 & up	V20	6DJ8	Trigger Shaper	154-187
	V37 A&B	6U8	Del. Trig. Ampl. & +Multi. Trig. Gate Gen.	154-033
	V43 A&B	6U8	-Multi. Trig. Gate Gen & Ready Ind.	154-033
101 - 13,343	V54	6BQ7A	Sw. Holdoff Cathode Follower	154-028
13,344 & up	V54	6DJ8	Sw. Holdoff Cathode Follower	154-187
101 - 13,343	V58 A&B	6BQ7A	+Multivibrator & Multi. C.F.	154-028
13,344 & up	V58 A&B	6DJ8	+Multivibrator & Multi. C.F.	154-187

TYPE 545

Vacuum Tubes Cont.

All changes made to Type 545 at SN 13,344 were made to RM45 at SN 306.

	V70	12BY7	-Multivibrator	154-047
101 - 13,343	V73 A&B	6BQ7A	Sweep-out C.F. & Gate-out C.F.	154-028
13,344 & up	V73 A&B	6DJ8	Sweep-out C.F. & Gate-out C.F.	154-187
	V78	6AU6	Multi-trace Units Sync Amplifier	154-022
	V80	6AL5	Disconnect Diodes	154-016
101 - 13,343	V85	6BQ7A	Sweep-generator C.F.	154-028
13,344 & up	V85	6DJ8	Sweep-generator C.F.	154-187
	V90	6CL6	Sweep Generator	154-031
	V113	12AU7	Trig. Ampl. C.F.	154-041
101 - 13,343	V120	6BQ7A	Trigger Amplifier	154-028
13,344 & up	V120	6DJ8	Trigger Amplifier	154-187
	V130	6U8	Trig. Shaper Ext. Sw. C.F.	154-033
101 - 13,343	V140	6BQ7A	Comparator	154-028
13,344 & up	V140	6DJ8	Comparator	154-187
101 - 13,343	V150 A&B	6BQ7A	Holdoff C.F. & Sweep-generator C.F.	154-028
13,344 & up	V150 A&B	6DJ8	Holdoff C.F. & Sweep-generator C.F.	154-187
	V155 A&B	6U8	-Multivibrator & +Multivibrator	154-033
101 - 13,343	V172 A&B	6BQ7A	Gate-out C.F. & Multivibrator C.F.	154-028
13,344 & up	V172 A&B	6DJ8	Gate-out C.F. & Multivibrator C.F.	154-187
	V180	12AL5	Disconnect Diodes	154-038
	V190	12AU6	Sweep Generator	154-040
101 - 6889	V195	6U8	Delay Pickoff	154-033
6890 & up	V195	6AU6	Delay Pickoff	154-022
Add 6890 & up	V196	6AU6	Delay Pickoff	154-022
	V216	6U8	Delay Trigger Shaper	154-033
	V228 A&B	6U8	Constant Current Tube & Delayed Trig. C.F.	154-033
101 - 13,343	V240 A&B	6BQ7A	Driver C.F. & Input C.F.	154-028
13,344 & up	V240 A&B	6DJ8	Driver C.F. & Input C.F.	154-187
101 - 13,343	V246 A&B	6BQ7A	Calibrator C.F. & Horiz. Pos. C.F.	154-028
13.344 & up	V246 A&B	12AU7	Calibrator C.F. & Horiz. Pos. C.F.	154-041
101 - 13,343	V265 A&B	6BQ7A	Sweep Amplifier & Sweep C.F.	157-022
13,344 & up	V265 A&B	6DJ8	Sweep Amplifier & Sweep C.F.	154-187
101 - 13,343	V272 A&B	6BQ7A	+Sweep Amplifier & -Sweep Amplifier	157-022
13,344 & up	V272 A&B	6DJ8	+Sweep Amplifier & -Sweep Amplifier	154-187
	V282	6CL6	Gated CF-current Booster	154-031
101 - 13,343	V670	6U8	Calibrator Multivibrator	154-033
13,344 & up	V670	6AU6	Calibrator Multivibrator	154-022
	V700	6AU6	-150 v DC Amplifier	154-022
	V710	5651	Voltage Reference	154-052
	V712	12AX7	-150 v Comparator	154-043
	V725	12B4	-150 v Series Regulator	154-044
	V726	12B4	-150 v Series Regulator	154-044
	V727	12B4	-150 v Series Regulator	154-044
	V742	6AU6	+100 v Comparator	154-022
	V748 A&B	6080*	+225 v & +100 v Series Regulators	154-056

Note: *May be a 6AS7GA, #154-116

TYPE 545

Miscellaneous

5001 & up	Bar, top support with handles	381-067
	Binding post, 5-way	129-001
	Binding post, ground	129-020
101 - 5000	Cabinet, one piece	437-018
5001 & up	Cabinet bottom plate	386-597
5001 & up	Cabinet left side w/stiffening crease	386-564
5001 & up	Cabinet right side w/recessed perforations	386-736
5001 & up	Cabinet right side, w/stiff. crease, w/o box for manual	386-565
5001 & up	Cabinet right side, w/stiff. crease, with bos for manual	386-719
5001 & up	Cabinet right side, w/recessed perf., with box for manual	386-770
10,037 & up	Cap, CRT anode	200-110
	Connector, 16-pin, female, for plug-in	131-018
	Connector, GE motor base, 2-wire	131-010
	Connector, Tek mfg. 3-wire	131-102
101 - 10,036	Connector, clip, anode, metal part only	131-026
101 - 10,036	Connector, clip, anode, w/rubber cover & 31" lead	131-040
10,037 & up	Connector, CRT anode, w/brush & 31" lead	131-086
RM45, SN 186	Connector, CRT anode, w/brush & 26½" lead	131-089
	Cord, power, 2-conductor (RM's 161-002)	161-004
	Cord, power 3-conductor (RM's 161-012)	161-010
101 - 10,036	Cover, anode, rubber, for 131-040	200-023
	Cover, CRT anode, for 131-086 & 131-089	200-111
	Dial for 30 k Helipot (CM of Delay or Delay Time Multiplier)	331-022
	Fan Blade, 7", clockwise, with rubber bushing	369-007
	Filter, air, 10 x 10 x 1	378-011A
	Graticule, 4cm x 10cm	331-034
	Handle	367-001
	Motor, fan	147-001
	Nut, graticule	210-424
101 - 5000	Panel, front	333-156
5001 - 5945	Panel, front	333-240
5946 - 7399	Panel, front	333-300
7400 - 9838	Panel, front	333-348
9839 & up	Panel, front	333-404
RM45	Panel, front	333-411
101 - 5000	Plate, access panel, plexiglass (2 per instrument)	386-310
5001 - 6776	Plate, access panel, plexiglass (1 per instrument)	386-560
6677 & up	Plate, access panel, deleted USE	013-008
	Plate, CRT anode	386-647
10,036 & up	Plug, CRT contact	134-031
	Probe tip, alligator clip assembly	344-005
	Probe tip, Tektip, hook	206-008
	Probe tip, Tektip, straight	206-009
101 - 5000	Receptacle, coax, Cal. Out	131-012
5001 & up	Receptacle, coax, Cal. Out	131-064
	Receptacle, coax, special cut (all positions except Cal. Out)	131-038
	Test Lead, 18" (replaces 012-013)	012-031