TYPE 535

Serial Numbers 101 through 6044

SUGGESTED FACTORY CALIBRATION PROCEDURE

Preset front-panel controls as follows:*

POWER SWITCH--OFF.
Main Sweep TRIGGERING LEVEL--0.
" " STABILITY--CCW.
TRIGGER SLOPE--+INT.
TRIGGERING MODE--AC SLOW.
TIME/CM--10 millisec.
MULTIPLIER--X1.
5X MAGNIFIER--OFF.
HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.

Delaying Sweep TRIGGERING LEVEL--0.
" " STABILITY--CCW.
SLOPE (toggle)--+.
ATTEN. (toggle)--X1.
TIME/CM OR DELAY TIME--1 millisec
HORIZONTAL POSITION--MS.
VERNIER--MS.
CALIBRATOR--OFF.
INTENSITY--CCW.

Preset R64 to CW. (This is a small screwdriver-slotted potentiometer control without shaft, situated at right center of top deck.)

Preset DELAY STOP ADJ to about 30° from CCW stop.

The following controls may be left at the settings where they are found--that is, they do not require presetting: (1) CAL ADJ, and (2) R99M--the latter being a small screwdriver-slot control mounted on the MULTIPLIER switch bracket.

Preset the remaining fourteen internal screwdriver-slotted controls to MS.

Preset the following capacitors to MS: C240, C254, C278, C286.

With no plug-in unit in position, check the resistances to ground of the lowvoltage power supplies. (While no tolerances are specified, it may be stated as a general guide that the resistance of the -150-volt supply usually runs in the neighborhood of 4,000 to 5,000 ohms. The resistances of the remaining supplies are progressively higher as you go to more positive voltages. The 500-volt supply might be expected to have a resistance of about 50,000 ohms.) If any two supplies appear to have the same resistance values, you should check for a possible short circuit between them.

Carry out the following calibration procedure:

1. To check relay time delay.--Remove high-voltage oscillator tube V803 (6AU5). With power-test plug-in unit in position, turn POWER switch on. Check that the time required for the relay to operate lies between 15 sec and 45 sec. (The thermal time-delay relay, K700, is rated for a 45-sec delay when 6 volts are applied to it. In the interest of positive contact operation, the relay is actually operated with about 9 volts applied, and the operating time may be appreciably less than 45 sec as a result.) Observe by the flickering of neon lamp NE95, located above V80 on the sweep chassis, that the main sweep

*Front-panel controls are indicated by UNDERLINED CAPITALS. Internal adjustments are indicated by PLAIN CAPITALS. These abbreviations are used: CW, clockwise; CCW, counter-clockwise; MS, mid-scale.

operates when you turn the Main Sweep STABILITY control CW. This flicker is readily discernible when the sweep operates at the 10-millisec/cm rate. (With the main sweep operating, it is probably safe to apply the high voltage to the CRT even if there should be a wiring defect in the circuits affecting the spot intensity.)

Turn the FOCUS and ASTIGMATISM controls CW. With the Main Sweep operating as above, insert the high-voltage oscillator tube, and observe that the trace can be turned on and off by means of the INTENSITY control. Now set the TIME/CM control to 100 μsec.

2. To check low-voltage power-supply operation.

   a. With 117 line volts applied, give a quick check to each low-voltage supply to determine that it is delivering approximately the correct voltage. This quick check helps to reveal overloads or other gross irregularities in operation.

   b. Set the -150 VOLTS ADJ control for precisely 150 volts output from the -150-volt supply.

   c. Check that the +100-volt supply delivers its rated output voltage within ±2%. Check that the +225-volt, +350-volt and +500-volt supplies deliver their rated voltages within ±3%. (For satisfactory operation of the vertical amplifier, the 350-volt supply must usually deliver at least 345 volts.) If a power-supply voltage falls outside these tolerances, proceed as follows:

      (1) Check that the supply affected is regulating (Part e below).

      (2) If a supply regulates, but if the voltage falls outside the tolerances given above, see that the supply is properly wired and tubed. In particular, see that normal screen voltages are applied to whichever of these tubes is involved in the affected supply: V700, V742, V757, V782 or V791. (See DC VOLTAGE MEASUREMENTS pamphlet.)

      (3) Try a different comparator tube (whichever of these tubes is involved in the affected supply: V712, V742, V765, V782 or V791).

      (4) Try a different set of precision resistors in the voltage divider in the affected supply.

      (5) Finally, if the above steps fail to bring the voltage within tolerance, install a 1/2-watt composition resistor beneath one or the other of the precision resistors in the voltage divider of the affected supply. Use a composition resistor of such value (usually several megohms) that the supply voltage is brought within the tolerance range.

   d. Set the test oscilloscope* for a sweep speed of 1 millisec/cm and the sweep speed multiplier to X5. Set the vertical sensitivity to 0.005 volts/cm. Using a 2X probe, determine that the power-supply ripple does not exceed 10 millivolts for the -150-volt, +100-volt and +225-volt supplies, and that the ripple does not exceed 15 millivolts for the +350-volt and the +500-volt

*It is assumed that a Type 531 test oscilloscope is used.

supplies. These ripple measurements are to be made at the power-supply output connections on the bottom deck of the oscilloscope. (The ripple voltages are usually appreciably smaller than the above outside tolerances. In particular, if the ripple on the -150-volt supply or on the +100-volt supply exceeds 3 or 4 mv, one should suspect a defective component or a wiring error. If components and wiring are good, however, the above tolerances apply.)

The predominant ripple frequency should be 120 cps, rather than 60 cps. This is evidenced by a display of approximately six cycles over the graticule of the test oscilloscope, when the sweep rate is 5 millisec/cm as set above.

e. Check the power-supply regulation by observing that the ripple voltages on the various supplies do not exceed approximately the tolerances given in Part d, above, as the line voltage and the loads are varied. Supplies must remain in regulation within the following operating limits:

Lower limit--line volts, 105; plug-in set at HI load.
Upper limit--line volts, 125; plug-in set at LO load.

NOTE:--If a supply fails to regulate, this failure may be caused by too small or too large a load, traceable to defective sweep circuits, vertical amplifiers, or other portions of the oscilloscope. In event of regulation trouble, do not confine your efforts to the affected supply, but make an effort to get all other parts of the instrument into approximately correct operation before deciding that the trouble is centered in the power supply.

3. To set CAL ADJ.--Use 117 line volts. With red calibrator knob turned to the OFF position, set CAL ADJ (bottom front of oscilloscope) for +100 volts at Pin 3 of V246 (best checked at the connection from that pin to the calibrator attenuator). The voltage at this point should drop to not more that +55 volts but not less than +45 volts when the red calibrator knob is turned to the MILLIVOLTS or to the VOLTS position, with the black calibrator knob in any position. (This last reading is to assure suitable calibrator symmetry.)

4. To adjust and check high-voltage supply.--

a. Observe that the high-voltage rectifier tubes are all lighted. If the brightness of the filaments is much different from one tube to another in the high-voltage supply, consider changing the high-voltage power transformer. Replace any high-voltage rectifiers exhibiting a blue glow between the elements, or having the glass cracked around the seals.

b. Set the -1350-volt output of the high-voltage supply to its rated value with the HV ADJ control. (Measure between the -150-volt supply output, and the first left-hand terminal of the ceramic strip adjacent to the CRT GEOM ADJ control. Use the 1200-volt range on the voltmeter.)

c. Check regulation of the -1350-volt output between these limits:

Lower limit--line volts, 105; INTENSITY advanced to produce a (defocused) spot or glow.
Upper limit--line volts, 125; INTENSITY at CCW, to produce no spot.

The regulation is observed by noting that the voltmeter reading remains nearly constant.

IMPORTANT--The above tests and adjustments are the ones normally required. Note that they do not directly indicate correct operation of the -1450-volt and the +8650-volt portions of the high-voltage power supply. If the -1450-volt portion of the supply is not operating correctly, you may have trouble in turning the spot off with the INTENSITY control, particularly when the sweep is operating; or you may experience trouble in obtaining a spot at all, particularly when the sweep is not operating. In cases of these kinds, you should also measure the -1450-volt output of the supply. If the +8650-volt output is not operating correctly, the trace may not display normal brightness on the fastest sweeps, even with the INTENSITY control turned well up. An even more important result of improper voltage from the + 8650-volt output is the effect upon horizontal and vertical deflection sensitivity. It must always be kept in mind that trouble with timing or with vertical gain might be due to incorrect operation of the +8650-volt supply circuits, rather than to the horizontal or vertical deflection systems. In some cases, it may be desired to measure the +8650-volt output, using two voltmeters in series; but you should remember that the loading effect of the measuring circuit can affect the reading.

5. To check sweep and vertical systems for operation.--Use 117 line volts.

a. Bring up INTENSITY control slowly from CCW position until a spot or glow appears on screen. Position spot on screen, keeping INTENSITY setting at minimum useful point. Bring up Main Sweep STABILITY control from CCW position until sweep is produced. Adjust FOCUS, INTENSITY and ASTIGMATISM controls to produce a trace of suitable sharpness and intensity.

b. Push CRT forward so that its face is against the graticule. Rotate CRT so that the trace coincides with the horizontal graticule line when properly positioned with the VERTICAL POSITION control. Clamp the CRT in position. Recheck the trace orientation.

c. Apply 0.2 volts from the calibrator to the input connector of the plug-in unit. With Main Sweep TRIGGERING LEVEL and Main Sweep STABILITY controls, obtain a stable trace. This operation gives a preliminary check on the operability of the triggering circuits.

Now observe the display from a position above and in front of the screen. Position the display to various parts of the screen by means of the position controls. Observe any waviness on the internal face of the CRT. Any appreciable waviness is cause for rejection of the CRT.

d. Set HORIZONTAL DISPLAY at DELAYING SWEEP position. Turn Main Sweep STABILITY CCW. Set Delaying Sweep TIME/CM at 1 millisec; set Delaying Sweep TRIGGERING LEVEL at 0. Connect VERT. SIG. OUT to TRIGGER OR EXT. SWEEP IN. With EXT. SWEEP ATTEN. switch at X1 and with SLOPE toggle switch at +, adjust Delaying Sweep STABILITY for stable sweep. Increase INTENSITY setting if necessary to view trace.

e. Using the settings of Part d above, set the Main Sweep TIME/CM control at 100 μsec and bring the Main Sweep STABILITY control CW to check that a portion of the sweep is brightened (during Main Sweep operation).

Now remove calibrator signal, leaving a single trace on the screen.

f. Check the oscilloscope for microphonics. This check is done by rapping on the test bench, or (not too forcibly) on the top of the panel. Experience will tell you how forcibly to rap and how much vertical deflection will occur in a correctly operating instrument as a result of microphonics. In any case, any definitely oscillatory type of microphonic display should indicate that a tube should be changed because of vibration of its elements. The 6CL6 vertical driver tubes, V508 and V509, are common sources of microphonics; other tubes in the vertical system may also be at fault. (Below SN 1059, 6BQ7's were used).

6. To adjust vertical AMPL GAIN.--Use 117 line volts. Apply 0.2 volts from calibrator to INPUT of power-test plug-in unit. Set AMPL GAIN control (on left side of oscilloscope, towards the rear) for 2 cm of vertical deflection (peak-to-peak). (This is a preliminary adjustment only.)

7. To adjust CRT GEOM control.--Use 117 line volts.

a. Apply more vertical signal from the calibrator than is needed to cover the graticule vertically. Position the display vertically so that the flat tops of the square waves are off the screen both above and below the graticule. Turn up the INTENSITY control so that the spot, moving rapidly in the vertical direction, makes a visible trace. Now set the CRT GEOM adjustment (rear of top deck) so that the vertical traces near the ends of the graticule are as nearly straight and vertical as possible.

In case the CRT is defective, a tilt may be observed in some of these traces. If the tilt exceeds 1 mm over the 6-cm height of the graticule, the CRT must be rejected.

b. As a further check on the CRT GEOM adjustment, remove the calibrator signal, and position the single trace first to the uppermost graticule line and then to the lowest graticule line. The trace should lie along the upper and the lower graticule lines without noticeable upward or downward bowing. A re-touching of the CRT GEOM adjustment should clear up any normal amount of bowing.

Observe whether or not a tilt is introduced into the trace at either the top or the bottom of the graticule. If the tilt in either trace position exceeds 1 mm over the 10-cm graticule length, the CRT must be rejected.

c. The CRT GEOM adjustment is often rather broad. Within the limits of its adjustments giving good results under Parts a and b of this step, use that setting which gives the least noticeable flare on the screen (when the SWEEP LENGTH control on the top deck of the oscilloscope, and the positioning controls, are set so that the display lies entirely within the graticule.)

8. To check for compression in the vertical system.--Apply a calibrator signal which provides 2 cm of vertical deflection when the display is centered vertically. This deflection should not be reduced by more than 0.5 mm when the display is raised to the top of the graticule or lowered to the bottom of the graticule by means of the VERTICAL POSITION control.

9. To check dc balance of vertical system.--

   a. Remove calibrator signal. Short-circuit vertical plates of CRT, and observe the trace position. With the short-circuit removed, adjust the VERTICAL POSITION control for the same position of the trace.

   b. Short-circuit Pins 2 and 7 of V606. Change V606 if the resulting vertical shift in trace position exceeds 0.25 cm. (If at any point in the present Step 9 it becomes necessary to interchange or replace tubes, redo Parts 5(f), 8 and 9(a).)

   c. Short-circuit Pin 2 of V570 to Pin 2 of V580. Interchange or replace these tubes if the resulting vertical shift in trace position exceeds 1 cm.

   d. Short-circuit Pins 2 and 7 of V558, and change V558 if the resulting vertical shift in trace position exceeds 1 cm.

   e. Short-circuit grid of V508 to grid of V509 by operating the push-button switch on the panel of the power-test plug-in unit. Interchange or replace these tubes if the resulting vertical shift in trace position exceeds 2 cm.

10. To check for vertical shift with varying line voltage.--The vertical position of the trace may shift as the power-line voltage is changed. This shift may be due to either or both of two independent causes: (1) a variation in emission unbalance with heater temperature of the 6CL6 or 6BQ7 vertical driver tubes, V508 and V509; or (2) a possible re-direction of the electron streams, because of the magnetic effects of the heater currents, causing a change in the screen-to-plate-current ratios in V508 and V509. To check for this vertical shift from either cause:

    With the HORIZONTAL DISPLAY switch at MAIN SWEEP NORMAL, and with the power-line voltage at 105 volts, obtain a single trace across the screen. Center this trace vertically with the VERTICAL POSITION control. Raise the line voltage to 125 volts. If any resulting (fast or slow) shift in vertical position of the trace exceeds 0.5 cm, try changing V508 or V509. (If these tubes must be changed, recheck Steps 5(f), 8, 9(a) and 9(e).)

11. To recheck vertical AMPL GAIN adjustment, and to check the calibrator attenuator.--

    a. Set the AMPL GAIN control so that 0.2 volts from the calibrator produces a vertical deflection of 2 cm.

    b. Replace the power-test plug-in unit with the 53/54C plug-in. Set the input selector at DC. Set the VOLTS/CM control at 0.05 and feed in 100 mv from the calibrator. Be sure that the red VARIABLE knob on the VOLTS/CM control is fully CW. A deflection of 2 cm should be obtained. Other positions of the calibrator attenuator should be checked similarly. The results should be those tabulated, within ±2%:

VOLTS/CM setting on plug-in unit	Calibrator attenuator setting	Vertical deflection
0.05	100 mv	2 cm
0.05	0.2 volts	4 "
0.1	0.5 "	5 "
0.2	1 "	5 "
0.5	2 "	4 "
1	5 "	5 "
2	10 "	5 "
5	20 "	4 "
10	50 "	5 "
20	100 "	5 "

12. To adjust DC SHIFT COMP control.--

a. After completing the above step, remove the calibrator signal from the INPUT connector. Leave the INPUT SELECTOR in the DC position. Set the MODE switch to "A ONLY" or to "B ONLY." Position the trace at - 3 cm (that is, 3 cm below the graticule center line).

b. Connect a 1.5-volt cell (or an ohmmeter) between GND on the oscilloscope and the plug-in unit connector. Adjust the VOLTS/CM control on the plug-in unit so that the trace moves to +3 cm. (That is, make the settings such that the trace is at -3 cm when the cell is disconnected, but rises to +3 cm when the cell is connected.)

c. Note the position of the trace immediately upon connecting the cell. Leaving the cell connected for several seconds, observe whether or not the trace slowly drifts 1 or 2 mm up or down. If it does, adjust DC SHIFT COMP control so that the drift occuring when the cell is connected is a minimum.

(NOTE: This step calls for connecting and disconnecting the cell several times, at intervals of several seconds, and observing that the trace comes at once to almost its final position, each time the cell is connected.)

13. To set TRIGGERING LEVEL controls to physical center.-- (For this adjustment, the TRIGGERING MODE control should NOT be set to AC AUTO.)

a. Connect a voltmeter from the junction of R16 and R17 to chassis. (R16 is connected to the center arm of the Main Sweep TRIGGERING LEVEL control, which is the control nearest the panel in the dual-control assembly of which it is a part.) Set the Main Sweep TRIGGERING LEVEL control so that zero deflection is obtained even on the 3-volt range of the voltmeter.

b. Loosen the Main Sweep TRIGGERING LEVEL knob on its shaft. Turn the knob on its shaft so that its index points to "0" on the panel, and tighten the knob on the shaft. Recheck that a voltmeter reading of zero is obtained when the knob index is at "0". Remove the voltmeter connections.

c. Now move the voltmeter ungrounded connection to the junction of R107 and R108. (R107 is connected to center arm of Delaying Sweep TRIGGERING LEVEL control.) Set the Delaying Sweep TRIGGERING LEVEL control so that zero deflection is obtained even on the 3-volt range of the meter.

d. Loosen the Delaying Sweep TRIGGERING LEVEL knob on its shaft. Turn the knob on its shaft so that its index points to "0" on the panel, and tighten the knob. Recheck that a voltmeter reading of zero is obtained when the knob index is at "0".

14. To adjust TRIGGERING LEVEL CENTERING.--Settings:

Main Sweep TRIGGERING LEVEL--0.	TIME/CM--1 millisec.
TRIGGER SLOPE--+INT.	5X MAGNIFIER--OFF.
TRIGGERING MODE--AC SLOW.	HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.

a. Display calibrator signal. Set calibrator output and the VOLTS/CM switch for 3 or 4 mm of vertical deflection. Set Main Sweep STABILITY control and the TRIGGERING LEVEL CENTERING control so that a stable display is obtained. Then make further adjustments of TRIGGERING LEVEL CENTERING so that the sweep triggers equally well on +INT and -INT settings of the TRIGGER SLOPE switch.

Note: The Main Sweep STABILITY control and the Main Sweep TRIGGERING LEVEL control may be touched up slightly to obtain the above result. The final setting of the Main Sweep STABILITY control will be in the vicinity of that needed just to produce triggering. The final setting of the Main Sweep TRIGGERING LEVEL control will be essentially at "0". After the TRIGGERING LEVEL CENTERING is adjusted, reliable triggering must be obtained as the TRIGGER SLOPE switch is moved back and forth between the +INT and the -INT positions without touching the Main Sweep TRIGGERING LEVEL or Main Sweep STABILITY controls.

The above is a preliminary adjustment of the TRIGGERING LEVEL CENTERING control. The final adjustment is described under Step 15, below.

b. Check the polarity of the TRIGGER SLOPE switch on +INT and -INT positions. The leading edge at the left end of the graticule should be a rising edge when the switch is in the +INT position, and it should be a falling edge when the switch is in the -INT position.

15. To adjust TRIGGER SENSITIVITY control.--Settings of the oscilloscope being calibrated:

Main Sweep TRIGGERING LEVEL--0.	TIME/CM--100 μsec.
Main Sweep STABILITY--CCW.	5X MAGNIFIER--OFF.
TRIGGER SLOPE--+LINE.	MULTIPLIER--X1.
TRIGGERING MODE--AC SLOW.	INTENSITY--CCW.
HORIZ. DISPLAY--MAIN SWEEP NORMAL.	

Settings of test oscilloscope:

TRIGGER SLOPE--+LINE.	TIME/CM--1 millisec.

TRIGGERING MODE--AC SLOW.
HORIZ. DISPLAY--INTERNAL SWEEP
5X MAGNIFIER--ON.
VOLTS/CM--2.

Connect 2X probe of test oscilloscope to Pin 1 of V20 (or to lead from that pin to the TRIGGERING MODE switch). With TRIGGER SENSITIVITY turned CW, the waveform of Fig. 1 should be seen on the test oscilloscope. (Figure may be inverted. If so, switch to -LINE triggering on test oscilloscope.)

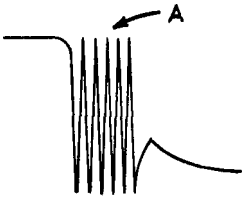

FIG. 1

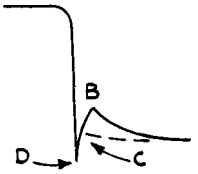

FIG. 2

The TRIGGER SENSITIVITY control should now be gradually turned CCW until the self-oscillation indicated at A just dies out. The result is a display shown in the solid line of Fig. 2. The TRIGGER SENSITIVITY control should be turned further in the CCW direction until the peak B drops to a point C (dotted line, Fig. 2) which has a height above D equal to one-half its original height.

After this adjustment, repeat Step 14(a), but this time obtain reliable triggering on signals which produce a vertical deflection of not more than a trace width.

Check that reliable triggering with a vertical deflection of not much more than a trace width occurs when the TRIGGERING MODE switch is set to AC FAST, and when the TRIGGER SLOPE switch is alternated between +INT and -INT as above.

16. To set INT TRIG DC LEVEL.--Display calibrator waveform at about 2 or 3 mm vertical deflection. KEEP THE DISPLAY CENTERED VERTICALLY about the graticule horizontal center line. Use these settings:

Main Sweep TRIGGERING LEVEL--0.
TRIGGER SLOPE--+INT.
5X MAGNIFIER--OFF.
HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.
TRIGGERING MODE--DC.
TIME/CM--1 millisec.
MULTIPLIER--X1

Adjust the Main Sweep STABILITY control and the INT TRIG DC LEVEL control for a stable trace. With correct adjustment of the INT TRIG DC LEVEL, the sweep will trigger equally well on +INT and on -INT slope settings, with a given setting of the Main Sweep STABILITY control.

17. To check AC AUTO operation.--Settings:

Main Sweep TRIGGERING LEVEL--CW.
Main Sweep STABILITY--CCW.
TRIGGER SLOPE--+INT.
TRIGGERING MODE--AC AUTO.
TIME/CM--100 μsec.
MULTIPLIER--X1
5X MAGNIFIER--OFF.
HORIZ. DISPLAY--MAIN SWEEP NORMAL

Use no signal input. Operation in the AC AUTO mode is indicated if, upon

advancing the Main Sweep STABILITY control slowly CW, you obtain a trace, and if further advance of this control results abruptly in a brightening of the trace. (The first trace results from triggering of the sweep by the trigger-shaper multivibrator operating in a free-running manner at about 50 cps. The brightening occurs when the sweep-generating circuits themselves become free-running at advanced Main Sweep STABILITY settings.

Now apply sufficient calibrator signal to provide 2mm of vertical deflection. Set the TIME/CM control to 1 millisec. A stable display should be obtained when the Main Sweep STABILITY control is set for triggered operation of the sweep. A further check on the AC AUTO mode is obtained by removing the input lead at the calibrator connector. Usually sufficient 60-cps signal will be picked up in the room so that if the bare end of the lead is held in the hand, a (distorted) ac wave can be obtained on the screen. The TIME/CM and VOLTS/CM controls should be set to obtain a display of suitable size on the screen, and it should be checked that a stable display can be obtained by setting the Main Sweep STABILITY control if necessary.

18. To adjust EXT SWP AMPL DC BAL.--Ground EXTERNAL SWEEP IN. Set:

HORIZONTAL DISPLAY--EXT SWP.
5X MAGNIFIER--ON.
Main Sweep STABILITY--CCW.
EXT. SWEEP ATTEN. (knob)--CW.
ATTEN. (toggle)--X1.

Position the spot on the screen by means of the HORIZONTAL POSITION control. Adjust EXT SWP AMPL DC BAL control so that the spot remains stationary on the screen as the EXTERNAL SWEEP ATTENUATOR knob is turned back and forth throughout its range.

19. To set C240 and C254.--Settings:

Main Sweep TRIGGERING LEVEL--0.
TRIGGER SLOPE--+EXT.
TRIGGERING MODE--AC SLOW.
HORIZONTAL DISPLAY--EXT. SWEEP.
SLOPE (toggle)--+
VOLTS/CM--10.
5X MAGNIFIER--ON.
ATTEN. (toggle)--X1.
EXT. SWP. ATTEN.--CW.
TIME/CM--1 millisec.
MULTIPLIER--X1.
CALIBRATOR--0.5 volts.

a. Connect 1-kc output from Type 105 to TRIGGER OR EXT. SWEEP IN. Have the Type 105 terminated at its output connector with a 52-ohm terminating resistor. Use a 52-ohm cable, terminated at the oscilloscope end in a 5:1 (14-db) 52-ohm L pad. Connect the Sync Output of the Type 105 to TRIGGER INPUT. Connect SAWTOOTH MAIN SWEEP to input of plug-in preamplifier. Adjust STABILITY for a stable square-wave display which is presented vertically, rather than horizontally, across the screen. Set the Output Amplitude control of the Type 105 for about 2 cm of horizontal deflection. Adjust C240 (at right rear of top deck) for best square-wave reproduction.

b. Next, turn the 5X MAGNIFIER off, and increase the Output Amplitude setting of the Type 105 so that a horizontal deflection of about 2 cm is again obtained. Adjust C254 (near C240) for best square wave reproduction.

Any horizontal instability observed in the display during this step should lead to a check of V113, V120 and V130 and their associated circuits for hum or noise.

20. To check SLOPE switch for correct polarity.--Using the same settings as for Step 19, check that (+) position of SLOPE toggle switch provides display at the right-hand side of the screen, while the (-) position of the switch moves the display to the left-hand side.

21. To adjust C110, C101 and C100. This operation is performed to adjust the horizontal-amplifier input capacitance to the standardized values.

    a. Use the same settings as for Step 19, with 5X MAGNIFIER on. The connection from the Type 105 to the TRIGGER OR EXT. SWEEP IN connector is now to be made through a 47-μμf Input Capacitance Standardizer (4X Atten.) (Stock No. 011-021) in place of the L pad used in Steps 19 and 20. Set the Type 105 Output Amplitude control for about 2 cm of horizontal deflection. With the fingers, adjust C110 (behind ATTEN. toggle switch) for best square-wave reproduction, meanwhile holding the handle of the SLOPE toggle switch with the other hand. (This adjustment will no longer be correct when the fingers are removed from C110; cabinet capacitance will later restore the waveform.) Operate the SLOPE toggle switch up and down rather fast during the adjustment of C110 to get a display which "alternates" to right and left sides of screen; this permits a better appraisal of the square wave. Consider only that portion of the waves extending vertically along the middle of the "alternating" display.

    b. Switch the ATTEN. toggle switch to X10. Repeat Part a of this step, but this time adjust with the fingers C100 (which affects the "slope" of the square wave) and C101 (which affects the "spike"). C100 and C101 interact.

    c. If the vertical center part of the display shifts to left or right when the SLOPE toggle switch is operated, suspect a gassy condition in V113 (12AU7), and change this tube.

22. To adjust delay line and to set vertical amplifier coils.--

    a. Insert special "high-frequency" plug-in unit, identified by its plastic chassis.*

    b. Check that the gray signal leads from Pins 1 and 3 of the preamplifier plug are clear of each other and clear of other wires. Similarly for the gray signal leads to the delay-line input coils. Use spudger, if necessary, to dress the cabled power leads back under the preamplifier plug and away from the gray signal conductors.

    c. Make sure that R570 and R580 (in vertical output amplifier), and leads to CRT vertical plates, are well away from each other and from other objects.

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*There is a possibility, as these instructions are being prepared, that the 53/54K plug-in unit may later be specified for this step, rather than the special high-frequency plug-in unit mentioned above.

d. Preset L570 and L580 (in vertical output amplifier) so that the slugs project about 3/16" below the lowest turns of the coils, as seen when the light source is placed on the opposite side of the translucent coil form from the viewer.

e. Preset the delay-line input coils so that the slugs are five turns in from their outermost position.

f. Settings:

Main Sweep TRIGGERING LEVEL--0.	HORIZONTAL DISPLAY--MAIN SWEEP NORMAL
Main Sweep TRIGGER SLOPE--+INT.	5X MAGNIFIER--OFF.

g. Feed a 300-kc to 500-kc square-wave output of Type 105 to input of plug-in unit. Have the Type 105 terminated at its output connector in a 52-ohm terminating resistor, and use a 52-ohm cable to the oscilloscope plug-in unit. Use a 5:1 (14-db) 52-ohm L pad at the oscilloscope end of the cable. Set the Type 105 Output Amplitude control for about 4 cm of vertical deflection.

h. The delay line affects only the first half microsecond of the square wave. Delay-line "trimmer" capacitors at the bottom of the oscilloscope affect the early part of the wave; upper capacitors affect later parts of the wave. The portion of the wave affected by a particular capacitor can be identified by the downward bump occurring when that capacitor is touched with the metal bit of a screwdriver.

CAUTION

The capacitors have +200 volts on them. Do not touch them with the fingers.

Adjust the capacitors of the delay line so that "wrinkles" of magnitude greater than the trace width are absent, and so that the "level" of the trace is constant across the top of the square wave. Avoid use of the first positive wave triggered on + slope. (This may have a slight curvature in these instruments.) Neglect irregularities appearing on the bottoms of the square waves--adjust only for flat tops or positive portions of the waves.

Suggestions:

Make only small changes in the capacitor adjustments. Typically, any one adjustment should be not more than that needed to raise or lower the corresponding portion of the display by an amount equal to a trace width.

Work always for maximum smoothness in the horizontal part of the display. Do not expect that a single adjustment of a capacitor will get the correct display height at any given point. Rather, work back and forth over a range of five or six capacitors at a time, making very small adjustments of the capacitors, and striving always to make the display smooth and free from sharp corners.

After each few adjustments, set the TIME/CM and MULTIPLIER switches

to slower sweep positions, so that the tops of the square waves line up closely together. This will show the effect (of the adjustments you have just made) upon the general "level" of the square-wave tops. It must be kept in mind that the finished delay line must transmit square waves whose tops appear consistently level, even when you use sweeps so slow that each wave top appears only about a millimeter in length.

A small residual wrinkle called a "termination bump" may sometimes remain at about the mid-point of the square wave. This should be adjusted for the least-noticeable value by setting the last (upper) one or two capacitors of the delay line when the sweep is set for about 1 μsec/cm. If the termination bump is excessive, the values of the line-terminating resistors R938 and R940 (775Ω each), and of the terminating capacitors C938 and C940 (1μμf each), should be checked.

i. After, and only after, the wrinkles have been eliminated and the general level of the square wave has been made satisfactory, try small increases in L570 and L580. Make equal small changes in these inductances. These changes have the effect of raising the level of the early portion of the wave. The level may be restored to normal by readjusting the first trimmer capacitors. The over-all result is a "squaring up" of the leading edge of the wave. This process is to be continued, a half-turn or a turn of each coil at a time, as far as practicable from the viewpoint of obtaining a good square-wave response.

j. The delay-line input coils should now be readjusted for increased inductance. These affect the leading edge only. Make equal small increases in both inductances. Then make any needed compensating adjustments of the first trimmer capacitors. Continue this process as far as practicable from the viewpoint of obtaining a good square-wave response.

Note: If the early part of the square wave persistently demonstrates overshoot, or if there is "ringing" (damped oscillation), then:

See that you do not have excessive inductance in the amplifier compensating coils L570 and L580, or in the input coils to the delay line.

See that fixed vertical-amplifier coils L557 and L560 (1.2 μh) and L634 and L635 (8.8μh) are correct. (For example, it would be easy to get some of these coils interchanged during assembly.)

Check the values of R634 and R635 (820 ohms) in the vertical-plate leads to the CRT. (If these resistors are low, overshoot may result. If they are high, it may be impossible to get the bandwidth required under Step 23, below.)

23. To check bandwidth of vertical system.--After completing the above step, feed into the plug-in unit connection a frequency in the lowest-frequency band of the Type 190. A 52-ohm terminating resistor should be inserted between the output cable attenuator of the Type 190 and the input connector of the oscilloscope.

With the TIME/CM control at 100 μsec, set the vertical deflection exactly upon some whole number of centimeters--say 3 cm or 4 cm. Without disturbing the other settings, increase the output frequency of the Type 190 untilthe deflection decreases to a value which is 70% of the original deflection. The frequency which gives this deflection is the 3-db-down frequency of the oscilloscope vertical system. Typical values obtained range from 12.1 mc to 12.3 mc. If the bandwidth is insufficient, recheck items 22b, 22c, 22i, and 22j.

24. To check HF SYNC operation.--Supply a 30-mc signal from the Type 190, with amplitude sufficient to produce 5 mm of deflection. Use these settings:

HORIZ. POSITION--MAIN SWEEP NORMAL.
Main Sweep TRIGGERING LEVEL--0.
TRIGGERING SLOPE--+INT.
TRIGGERING MODE--HF SYNC.
TIME/CM--0.1 μsec.
MULTIPLIER--X1.
5X MAGNIFIER--ON.
Delaying Sweep STABILITY--CCW.

A setting of the Main Sweep STABILITY control should be found at which the 30-mc sine-wave display is stable.

25. To adjust SWP CAL.--Insert a Dual Trace Preamplifier (53C or 53/54C plug-in unit may be used). Settings:

HORIZONTAL DISPLAY--DELAYING SWEEP.
SLOPE (toggle)--+.
5X MAGNIFIER--OFF.
Delaying Sweep TIME/CM--1 millisec.
LENGTH--CW.

Connect a jumper from VERT.SIG. OUT to TRIGGER OR EXT. SWEEP IN. Display 1-millisec markers from Type 180, and adjust Delaying Sweep STABILITY and Delaying Sweep TRIGGERING LEVEL for stable display. Keeping the second marker precisely beneath the 1-cm graticule line with the HORIZONTAL POSITION control, adjust the SWP CAL control so that the tenth marker falls precisely under the 9-cm graticule line.

26. To set the Delaying Sweep LENGTH.--Set the Delaying Sweep to free-run at 1 millisec/cm. Connect the middle (black) wire of the "resistance selector" to the upper end of the 12-K resistor, R182, in the Delaying Sweep chassis. Connect the right-hand (red) wire to the lower end of R182. Connect the left-hand (red) wire to the upper end of R180 (15-k). Set the knobs of the "resistance selector" to values that make the shortest sweep obtainable with the LENGTH control lie between 3.2 and 3.8 cm, while making the longest sweep obtainable with the LENGTH control lie between 10.3 and 10.8 cm. Remove the "resistance selector" cables from the Type 535. Connect a $\frac{1}{2}$-watt carbon resistor (R181-B) having the value shown on the left dial of the "resistance selector" between the upper ends of R182 and R180. Connect a $\frac{1}{2}$-watt carbon resistor (R182-B) having the value shown on the right dial of the "resistance selector" across R182. Recheck the range of sweep lengths obtainable by operation of the LENGTH control.

27. To time main sweep to delaying sweep.--Settings:

HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.
TRIGGER SLOPE--+INT.
TRIGGERING MODE--AC SLOW.
5X MAGNIFIER--OFF.
TIME/CM--1 millisec.
MULTIPLIER--X1.

Display 1-millisec markers from Type 180, and adjust Main Sweep STABILITY and Main Sweep TRIGGERING LEVEL controls for stable display. Keeping the second marker precisely beneath the 1-cm graticule line with the HORIZONTAL POSITION control, adjust R99M (on Main Sweep TIME/CM switch bracket) so that the tenth marker falls precisely under the 9-cm graticule line.

28. To adjust main SWP LENGTH.--With the same settings as those used in Step 27, adjust SWP LENGTH control for sweep of $10\frac{1}{2}$ cm.

29. To adjust MAG GAIN.--

a. With the same settings as those used in the step just completed, feed in 1-millisec and 100-μsec markers from Type 180. Adjust Main Sweep STABILITY and Main Sweep TRIGGERING LEVEL controls for a stable display.

b. Now turn 5X MAGNIFIER on. With the HORIZONTAL POSITION control, set the sixth 1-millisec marker approximately under the vertical center line of the graticule.

c. Adjust MAG GAIN and HORIZONTAL POSITION so that 100-μsec markers fall precisely under the 1-cm and the 9-cm graticule lines, with two markers for each cm of distance between these lines. At graticule lines within the middle 8 cm, the markers should align with the graticule lines within a tolerance of ±1 mm.

30. To adjust SWP/MAG REGIS.--After completing the above step, position the first marker beneath the graticule center line by means of the HORIZONTAL POSITION control. Then turn the 5X MAGNIFIER off, and by means of the SWP/MAG REGIS control, reposition the first marker beneath the center line.

31. To check the main sweep timing, 5-sec/cm to 100-μsec/cm ranges.--After completing the step above, turn the 5X MAGNIFIER off. Then

a. Switch the TIME/CM control to 100 μsec. Position the second marker precisely under the 1-cm graticule line by means of the HORIZONTAL POSITION control. Check that the markers coincide with the graticule lines within ±1%, over the middle 8 cm of the graticule length.

b. Reset the TIME/CM switch to 1 millisec. Turn off the 100-μsec markers on the Type 180, and make any needed readjustment of the TRIGGERING LEVEL to obtain a stable display of the 1-millisec markers. Set the MULTIPLIER to X2. Position the third 1-millisec marker precisely under the 1-cm graticule line with the HORIZONTAL POSITION control. Check the timing over the middle 8 cm of the graticule length. (Two markers should be obtained for each cm of graticule length.) Tolerance, ±1%.

c. Repeat Part b of this step, this time using only 5-millisec markers. Have the TIME/CM switch in the 1-millisec position, and the MULTIPLIER in the X5 position. With the second marker positioned under the 1-cm graticule line, you should obtain 1 marker/cm within a tolerance of ±1%, over the middle 8 cm of the graticule length.

d. Now apply only 1-millisec markers. With the TIME/CM switch in the 1-millisec

position and with the MULTIPLIER in the 2.5-1 position, check that the red variable multiplier knob provides control of the number of markers per cm over at least the range from 2.5 to 1.

e. With the MULTIPLIER in the 5-2 position, check that the red variable multiplier knob provides control of the number of markers per cm over at least the range from 5 to 2.

f. Turn the black MULTIPLIER knob to the 12-5 position, and set the red variable multiplier knob CW. Switch to a TIME/CM position of 100 μsec. Six markers should appear, approximately filling the graticule space horizontally. At least 13 markers should appear in the same horizontal space when the red variable multiplier knob is turned CCW.

g. Set TIME/CM at 10 millisec and MULTIPLIER at X1. Feed in 10-millisec markers only from Type 180. With the second marker positioned under the 1-cm graticule line, check that the timing (1 marker/cm) is within a ±1% tolerance over the middle 8 cm of the graticule.

h. Repeat Part g of this step, this time using 100-millisec markers and a TIME/CM setting of 100 millisec. Tolerance, ±1%.

i. Inserting 1-sec markers, and using a TIME/CM setting of 1 sec, check the timing of the sweep with MULTIPLIER settings of X1, X2 and X5. Tolerance, ±1%. (On X1 position, one marker/cm should be observed. On X2, two markers/cm should be observed. On X5, five markers/cm should be observed.)

32. To set timing of main sweep, 10-μsec/cm to 0.1-μsec/cm ranges.--

a. Preset C278 and C286 to mid-range positions.

b. With TIME/CM switch at 10 μsec and with MULTIPLIER at X1, display 10-μsec markers. With the HORIZONTALPOSITION control, keep the second marker precisely under the 1-cm graticule line. Adjust C99F (on TIME/CM switch) so that the 10th marker lies precisely under the 9-cm graticule line. Correct timing (1 marker/cm) should be obtained within the middle 8 cm of graticule length, within a tolerance of ±1%.

c. Repeat Part b of this step. This time, display 1-μsec markers with a TIME/CM setting of 1 μsec. In this part, adjust C99H (on TIME/CM switch).

d. Set TIME/CM at 0.1 μsec and MULTIPLIER at X5. Insert 1-μsec markers. Position the first marker off the screen to the left, with the HORIZONTAL POSITION control, and position the second marker under the 1-cm graticule line. Maintaining this position of the second marker precisely with the HORIZONTAL POSITION control, adjust C99J (on TIME/CM switch) so that the sixth marker lies precisely under the 9-cm graticule line. Correct timing (two cm between markers) should be obtained within the middle 8 cm of graticule length, within a tolerance of ±1%.

e. Set TIME/CM at 0.1 μsec and MULTIPLIER at X1. Display 10-mc sine waves from the Type 180. Touch up C254 and adjust C267 (the latter is mounted near the

MAG. GAIN control) for best linearity and timing of the display, obtaining one cycle of the sine wave for each cm of graticule length, over the middle 8 cm of graticule length. Settings of C254 and C267 interact; C254 serves principally to set the sweep speed, while C267 serves principally as a linearity adjustment.

f. Recheck Part c of this step. Then, displaying 1-μsec markers with a TIME/CM setting of 1μsec/cm, check the timing with the MULTIPLIER on the X2 position. Over the middle 8 cm of the graticule, you should observe 2 markers/cm, within a tolerance of ±1%. (Note: If C240 or C254 are very far out of adjustment, you may get an effect which could lead you to believe that the multiplier resistors are out of tolerance. C254 has been retouched in Part e of this step, above. If the present check on the MULTIPLIER X2 position seems out of tolerance, you may wish to recheck the adjustment of C240, as given in Step 19, before trying new multiplier resistors.)

g. Displaying 5-μsec markers with a TIME/CM setting of 1 μsec/cm, check the timing with the MULTIPLIER on X5 position. Over the middle 8 cm of the graticule, you should observe 1 marker/cm, within a tolerance of ±1%. (The note attached to Part f of this step, above, also applies here.)

h. Recheck Parts d and e of this step, until no further adjustments under these steps are required.

33. To adjust C278 and C286.--Settings:

Main Sweep TRIGGERING LEVEL--0.
Main Sweep TRIGGER SLOPE--+INT.
TRIGGERING MODE--AC SLOW
HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.
Main Sweep TIME/CM--0.1 μsec.
MULTIPLIER--X1.
5X MAGNIFIER--ON.

Connect 1-μsec marker output of Type 180 to INPUT of plug-in unit. Capacitively couple the 50-mc output of the Type 180 to one of the vertical plates of the CRT. (The value of the coupling capacitor is not at all critical. A suggested value is 20 μμf.) Set the Main Sweep STABILITY control for a stable display of the 50-mc sine wave. Make these adjustments:

a. Set the HORIZONTAL POSITION control at about the position of 1100 hours (slightly CCW from mid-scale). Set the VERNIER at mid-scale. Adjust C278 and C286 (keeping them approximately balanced with respect to each other) for best timing and linearity of the display. There should be precisely eight cycles of the sine-wave display over the middle 8 cm of the graticule length. Within the middle 8 cm of the graticule, there should be one cycle of the sine wave for each centimeter of the graticule length.

b. Turn the HORIZONTAL POSITION and VERNIER knobs CCW. If these settings bring into view the last few cycles of the display, which are obviously nonlinear, then reset the VERNIER knob towards CW until these nonlinear portions are positioned off the right end of the graticule. There should now be eight cycles of the sine-wave display over the middle 8 cm of the graticule length. Within the middle 8 cm of the graticule, there should be one cycle of the sine wave for each centimeter of graticule length, within a tolerance of ±2%.

c. Turn the HORIZONTALPOSITION knob CW until the left end of the display becomes visible. Now turn the knob a short way CCW until the first few cycles, which are obviously nonlinear, are positioned off the left end of the screen. Check the trace for eight cycles of the sine wave over the middle 8 cm of the graticule length. Within the middle 8 cm, there should be one cycle of the sine wave for each centimeter of graticule length, within a tolerance of ±2%.

Note: If it is not possible to obtain the results described for this operation, and if parts and tubes in the sweep and sweep-amplifier circuits are good and are properly connected, then the fault probably lies in the way in which Steps 19 and 32 were carried out, so that it is wise in case of difficulty to recheck these steps.

34. To check the horizontal gain.--Settings:

HORIZONTAL DISPLAY--EXT. SWEEP.
EXT. SWEEP ATTEN.--CW.
5X MAGNIFIER--ON.
SLOPE (toggle)--+.
ATTEN. (toggle)--X1.

Feed 0.2 volt from the calibrator to TRIGGER OR EXT. SWEEP IN. Position the sweep on the screen with the HORIZONTAL POSITION control. Length of sweep should be not less than 1 cm.

Now increase the calibrator output to 2 volts. Adjust EXT. SWEEP ATTEN. knob for a horizontal deflection of 10 cm. Throw the ATTEN. toggle switch to the X10 position, and turn the calibrator output to 20 volts. The new horizontal deflection should be 10 cm ±1 minor division. This procedure checks the correctness of the attenuation ratio of the X10 fixed attenuator.

35. To set DELAY START ADJ and DELAY STOP ADJ.--Settings:

Main Sweep TRIGGERING LEVEL--CW or CCW.
Main Sweep STABILITY--CW.
TRIGGER SLOPE--+INT.
Main Sweep TIME/CM--10 μsec.
MULTIPLIER--X1.
HORIZONTAL DISPLAY--DELAYING SWEEP.
5X MAGNIFIER--OFF.
Delaying Sweep TIME/CM--500 μsec.
LENGTH--CW.
SLOPE (toggle)--+.
ATTEN. (toggle)--X1.

a. Advance Delaying Sweep STABILITY to obtain trace. Adjust INTENSITY for moderate brightness. Observe that a short brightened region (due to Main Sweep unblanking) appears on trace. The brightened portion should move along the trace when the DELAY-TIME MULTIPLIER is turned.

b. Connect VERT. SIG. OUT to TRIGGER OR EXT SWEEP IN. Display 500-μsec markers from Type 180. Adjust Delaying Sweep STABILITY and TRIGGERING LEVEL for stable display. Align display with graticule, using HORIZONTAL POSITION control.

c. Check the registration of the DELAY-TIME MULTIPLIER dial. Dial should read 0.0 when the knob is rotated CCW until stop is reached.

d. Set DELAY-TIME MULTIPLIER 1.0. With DELAY START ADJ., make the left end of the brightened portion of the trace coincide with the 1-cm marker. (The left end of the brightened section of the trace indicates the start of the main sweep.) Then, set the DELAY-TIME MULTIPLIER at 9.0. With DELAY STOP ADJ., make the left end of the brightened portion of the trace coincide with the 9-cm marker. These adjustments result in preliminary adjustments of DELAY START ADJ. and of DELAY STOP ADJ.

e. At this point, check the delay-pickoff system for jitter. To do this, set the Delaying Sweep TIME/CM control to 1 millisec, and the Main Sweep TIME/CM control to 1 μsec. Display 500-μsec markers with the HORIZONTAL DISPLAY control at DELAYING SWEEP. Set the DELAY-TIME MULTIPLIER so that the brightened portion of the sweep approximately coincides with the marker which appears at the 2-cm graticule line. Switch the HORIZONTAL DISPLAY control to MAIN SWEEP DELAYED, and make any slight readjustment of the DELAY-TIME MULTIPLIER needed to place the magnified marker on the screen. Horizontal jitter in the marker position should not exceed 2 mm. (Neglect slow drift in marker position.)

Now turn the HORIZONTAL DISPLAY control back to DELAYING SWEEP, and set the DELAY-TIME MULTIPLIER so that the start of the brightened portion of the trace approximately coincides with the marker which appears at the 9-cm graticule line. Switch the HORIZONTAL DISPLAY control to MAIN SWEEP DELAYED, and make any slight readjustment of the DELAY-TIME MULTIPLIER required to place the magnified marker on the screen. Horizontal jitter in the marker position should not exceed 5 mm. (Neglect slow drift of marker position.)

If the jitter in either of the above tests exceeds specifications, you can try changing V180 (12AL5), which may be hummy, noisy or photosensitive. You can also try changing V190 (12AU6) or V195 (6U8). A poorly-grounded socket or an improperly-placed ground connection, particularly in the region of V195 or V216, can also result in jitter.

Now reset the Delaying Sweep TIME/CM control to 500 μsec and the Main Sweep TIME/CM control to 10 μsec.

f. Preliminary settings of DELAY START ADJ. and of DELAY STOP ADJ. were obtained in Part d of this step. These controls must now be brought into final adjustment. The adjustments of DELAY START ADJ. and of DELAY STOP ADJ. interact. These adjustments should be repeated so that the final adjustments are as nearly accurate as possible at both the 1-cm marker and at the 9-cm marker.

(Some workers prefer, after getting a close initial adjustment as above, to make final adjustments with the HORIZONTAL DISPLAY switch in the MAIN SWEEP DELAYED position. Here, the coincidence of the marker with the start of the main sweep is seen directly.)

Adjustment of the DELAY START ADJ. control produces approximately equal effects at the 1-cm and at the 9-cm positions. Adjustment of the DELAY

STOP ADJ. control produces about one-tenth the effect at the 1-cm position as at the 9-cm position. Various "tricks," based on these relationships, have been devised to get a quick initial adjustment of DELAY START ADJ. and DELAY STOP ADJ. One of these tricks is as follows:

Observe the error (which we shall call E_9) at the 9-cm point. The error is indicated by the number of minor divisions by which it is necessary to displace the DELAY-TIME MULTIPLIER from its 9.0-cm reading in order to make the start of the brightening coincide with the 9-cm marker. (A positive error is one which puts the brightening too far to the right of the marker.) Next, observe the error at the 1-cm point. Call this error E_1. With the DELAY START ADJ., correct the 1-cm error by an amount

$$C_1 = \frac{10E_1 - E_9}{9} \text{ minor divisions.}$$

(If C_1 is positive, move the brightened section to the left.) Then, with the DELAY-TIME MULTIPLIER at 9.0, set the DELAY STOP ADJ. so that the left end of the brightening coincides with the 9-cm marker. Now make any necessary final adjustments of the DELAY START ADJ. at the 1-cm point, and of the DELAY STOP ADJ. at the 9-cm point.

36. To check the Delaying Sweep linearity on the 500-μsec/cm range.--After completing Step 35, check that the left end of the trace brightening coincides with the 2-cm marker, the 3-cm marker, etc., when the DELAY-TIME MULTIPLIER is set at the 2.0, the 3.0, etc., positions, for each major graticule line within the middle 8 cm of graticule length. Maximum permissible error in this indication is 2 minor divisions on the DELAY-TIME MULTIPLIER.

37. To check DELAY-TIME MULTIPLIER indications on ranges from 10 millisec/cm to 200-μsec/cm.--After completing Step 36, display 100-μsec/cm markers from the Type 180, using the 200-μsec/cm position on the Delaying Sweep TIME/CM control. Observe the displacement in minor divisions of the DELAY-TIME MULTIPLIER dial from the 1.0 position required to make the left end of the brightened portion of the trace coincide with the 1-cm marker. Next, observe the corresponding displacement at the 9-cm position. The difference between the displacements must not be more than 5 minor divisions.

Carry out this process on all ranges from 10 millisec/cm to 200 μsec/cm. On each range, use an appropriate marker rate from Type 180. The 500 μsec/cm range does not have to be rechecked; it has already been adjusted by means of the DELAY START ADJ. and DELAY STOP ADJ. On no range is the difference between the displacements to be greater than 5 minor divisions.

(In each operation in this step, use settings of the Main Sweep TIME/CM and MULTIPLIER which will make the length of the brightened region satisfactory to the person doing the calibration. Also, in each operation, use a marker period selection on the Type 535 which is suitable for the range being checked on the Type 535 Delaying Sweep TIME/CM switch.)

It is advisable to make, during the above check, a table showing the displacements obtained. This table, which may be discarded after the calibration, helps to identify which component may be at fault if the 5-minor-division tolerance is not met on any range or ranges. An example of such a table follows (indicating, in this particular case, satisfactory compliance with the tolerance requirements).

Range (Delaying Sweep TIME/CM switch)	Displacement in minor divisions at 1 cm	9 cm
200 µsec/cm	-1.2	+1.1
500 µsec/cm	0	0
1 millisec/cm	+2.3	+2.4
2 "	-1.3	+1.2
5 "	-0.4	-0.2
10 "	+2.0	+2.1

38. To adjust C190-D and to check the linearity of the DELAY-TIME MULTIPLIER indication on the 50-µsec/cm range.--Use the same settings as for Step 35, except that the Main Sweep TIME/CM switch should be at 1 µsec/cm, and the Delaying Sweep TIME/CM switch should be at 50 µsec/cm.

a. Same as Part a of Step 35.

b. Connect VERT. SIG. OUT to TRIGGER OR EXT SWEEP IN. Display 50-µsec/cm markers from Type 180. Adjust Delaying Sweep STABILITY and TRIGGERING LEVEL for stable display. Make a preliminary adjustment of C190-D (situated on Delaying Sweep TIME/CM switch), obtaining about 1 marker per cm of graticule length. Align the display with the graticule, using the HORIZONTAL POSITION control.

c. Set the DELAY-TIME MULTIPLIER so that the left end of the brightened portion of the trace coincides with the 1-cm marker. Observe the deviation, in minor divisions, of the dial reading from 1.0.

d. Set the DELAY TIME MULTIPLIER dial for the same deviation from 9.0 as that observed from the 1.0 position in Part c. Adjust C190-D for coincidence of the left end of the trace brightening and the 9-cm marker.

Here, and in the final adjustment under Part e of this step, below, the actual amount of the deviation obtained is not the essential thing. (Because of the time required for the triggering circuits to operate, the deviation may be five or ten minor divisions, or even more, at both ends of the adjustment range. This is even more apparent when adjusting on the 5-µsec/cm range, in Step 39, below.) The important thing is that the amounts of the deviations should be the same at the 1-cm and at the 9-cm points on the sweep.

e. The adjustment made in Part d will change the deviation at the 1.0-cm marker. Therefore, Parts c and d must be repeated several times, or until the same deviations from 1.0 and 9.0 dial readings occur for coincidence of the left end of the trace brightening with the 1-cm or with the 9-cm marker.

f. The linearity of the DELAY TIME MULTIPLIER indications on this range must now be checked in the manner of Step 36. Use 50-μsec markers.

39. To adjust C190-F and to check the linearity of the DELAY-TIME MULTIPLIER indication on the 5-μsec/cm range.--Proceed as in Step 38, except that here you use the 5-μsec/cm range of the Delaying Sweep TIME/CM switch, and display 5-μsec markers from the Type 180. Use 0.1-μsec/cm speed on Main Sweep. Adjust C190-F instead of C190-D.

40. To check Delaying Sweep for operation on the 100-μsec/cm to 2μsec/cm ranges.--Settings:

Main Sweep TRIGGERING LEVEL--CW or CCW.
Main Sweep STABILITY--CW.
TRIGGER SLOPE--+INT.
MULTIPLIER--X1.
HORIZONTAL DISPLAY--DELAYING SWEEP.
5X MAGNIFIER--OFF.
LENGTH--CW.
SLOPE (toggle)--+
ATTEN. (toggle)--X1.

With VERT. SIG. OUT connected to TRIGGER OR EXT. SWEEP IN, display successively the markers listed below at the Delaying Sweep speeds indicated. For each display, use Main Sweep speed shown. In each case, observe that the Delaying Sweep functions so as to produce a trace, and that the brightening indicative of Main Sweep triggering by the Delay Pickoff occurs.

Marker Interval from Type 180	Delaying Sweep TIME/CM	Main Sweep TIME/CM
1 μsec	2 μsec/cm	0.1 μsec/cm
10 μsec	10 μsec/cm	1 μsec/cm
10 μsec	20 μsec/cm	1 μsec/cm
100 μsec	100 μsec/cm	10 μsec/cm

41. To check the Delaying Sweep for 50-kc repetition rate.--Operate the Delaying Sweep in a free-running manner, with the Delaying Sweep TIME/CM switch at the 2-μsec/cm position and with the LENGTH control set CCW. Connect a test oscilloscope 10X probe to the right-hand end of C240. Observe the Delaying Sweep waveform, using a test oscilloscope sweep speed of 10 μsec/div. Each cycle of the waveform, including holdoff, should require not more than 2 major divisions on the test oscilloscope screen.

42. To check waveforms of both sweeps for sufficient holdoff.--

a. After completing Step 41, turn the Delaying Sweep LENGTH control CW. Set the Delaying Sweep for free-running. Connect 10X probe of test oscilloscope to right hand end of C240. Observe waveforms on all sweep speeds obtained by turning the Delaying Sweep TIME/CM switch. Have test oscilloscope set for DC input. Holdoff in each case should be sufficient to prevent any retrace transients from extending into trace. As a general guide, the horizontal interval from the end of retrace to beginning of trace usually has a duration of 5 μsec or more. This does not apply to the Delaying Sweep ranges of 2 μsec, 5 μsec and 10 μsec.

b. Settings:

Main Sweep TRIGGERING LEVEL--0.	HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.
Main Sweep STABILITY--Set for free-run.	5X MAGNIFIER--OFF.
TRIGGER SLOPE--+INT.	MULTIPLIER--X1.
TRIGGERING MODE--AC SLOW.	Delaying Sweep STABILITY--CCW.

Repeat observations of Part a of this step using Main Sweep TIME/CM switch. Horizontal interval of Main Sweep holdoff should generally be at least 5 μsec.

43. To adjust R64 for proper waveform at Pin 8, V37-B.--Settings:

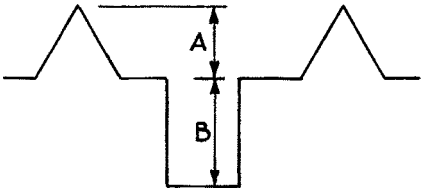
HORIZONTAL DISPLAY--DELAYING SWEEP.	Main Sweep TRIGGERING LEVEL--0.
Main Sweep TIME/CM--100 μsec.	Delaying Sweep TRIGGERING LEVEL--0.
MULTIPLIER--X1.	Delaying Sweep STABILITY--CW.
5X MAGNIFIER--OFF.	Delaying Sweep TIME/CM--200 μsec.
TRIGGER SLOPE--+INT.	LENGTH--CW.
TRIGGERING MODE--AC SLOW.	

Use no signal input to vertical system of oscilloscope under calibration. Connect 10X probe of test oscilloscope to Pin 8, V37-B. Use the following settings of test oscilloscope:

TIME/CM--100 μsec.	TRIGGER SLOPE--+INT.
MULTIPLIER--X5.	VOLTS/CM--1.
5X MAGNIFIER--OFF.	

IMPORTANT: In the following adjustment, constantly have the Main Sweep STABILITY control sufficiently clockwise to allow reliable triggering--but no further clockwise.

This waveform should be observed on the test oscilloscope:



Adjust R64 so that the height of the peak A is two-thirds that of the pedestal B.

The ratio of the height of the peak A to the height of the pedestal B is ideal when A is two-thirds of B. However, A may actually be larger than two-thirds of B, even when R64 is adjusted to the end of its range. This result is satisfactory, as long as A is not larger than B. In all cases, pedestal B must have an amplitude of at least 9 volts.

To get a satisfactory adjustment, if the control R64 runs against its stop before the result is suitable, you may have to change R65 (39K) or R66 (33K), connected to R64. Or you may have to change R50 (95K precision) or R51 (220K precision), which are connected in the plate circuit of V43A.

44. To check waveforms available on panel terminals.--Observe waveforms as follows with test oscilloscope:

a. +GATE, MAIN SWEEP.--This should be a rectangular wave with an amplitude of

18 to 35 volts. It should be observed with the Main Sweep free-running.

b. SAWTOOTH, MAIN SWEEP.--This sawtooth wave should have an amplitude of 135 to 165 volts. It should be observed with the Main Sweep free-running.

c. DEL'D TRIG. FROM MAIN OR DEL'G. SWEEP.--Settings on oscilloscope being tested:

HORIZONTAL DISPLAY--DELAYING SWEEP.
Main Sweep TRIGGERING LEVEL--0.
Main Sweep STABILITY--CW.
TRIGGER SLOPE--+INT.
TRIGGERING MODE--AC SLOW.
Main Sweep TIME/CM--10 μsec.
Delaying Sweep TRIGGERING LEVEL--0.
Delaying Sweep STABILITY--CW.
Delaying Sweep TIME/CM--10 μsec.

Using a 2X probe, observe on the test oscilloscope, the output from the DEL'D TRIG. FROM MAIN OR DEL'G SWEEP connector. Use these settings for the test oscilloscope:

TRIGGER SLOPE--+INT.
TIME/CM--10 μsec.
MULTIPLIER--X5.
VOLTS/CM--0.5 AC.

You should observe on the test oscilloscope positive triggers of 5 to 10 volts amplitude, and negative triggers of about 0.5 volt amplitude. The time relationship between the + and - triggers should be controllable by means of the DELAY TIME MULTIPLIER. The spacing of the triggers should be adjustable by means of the Delaying Sweep LENGTH control of the oscilloscope being calibrated.

Now turn the HORIZONTAL DISPLAY control to the MAIN SWEEP DELAYED position. The above results should again be obtained.

Next, turn the HORIZONTAL DISPLAY control to the MAIN SWEEP NORMAL position. A display similar to that obtained above should appear on the test oscilloscope--this time unaffected by adjustment of the Delaying Sweep LENGTH control. (The spacing of the triggers may be somewhat different from that obtained on the DELAYING SWEEP and MAIN SWEEP DELAYED positions, due to a difference in sweep lengths and holdoff times in the Main Sweep and in the Delaying Sweep.)

d. +GATE, DEL'G SWEEP.--This should be a rectangular wave with an amplitude of 18 to 35 volts. It should be observed with the Delaying Sweep free-running.

e. VERT. SIG. OUT.--Insert calibrator signal into plug-in input. Reproduction of the square wave should be obtained at VERT. SIG. OUT. This reproduction is only approximate because the response of the channel which feeds this terminal is restricted to about 20 cps to 6 mc. The amplitude of reproduction is about 2 volts for each centimeter of deflection.

f. 6.3 V 1A. AC.--Using the 2X probe, you should set the test oscilloscope as follows:

TRIGGER SLOPE--+LINE.
TIME/CM--1 millisec.
MULTIPLIER--X5.
VOLTS/CM--2 AC.

A wave of approximately sinusoidal form and of about 18 volts (9 divisions) peak-to-peak amplitude should be observed.

45. To check reset of Main Sweep.--Settings:

Main Sweep TRIGGERING LEVEL--0.	5X MAGNIFIER--OFF.
TRIGGER SLOPE--+INT.	Delaying Sweep TRIGGERING LEVEL--0.
TRIGGERING MODE--AC SLOW.	Delaying Sweep STABILITY--CCW.
Main Sweep TIME/CM--1 millisec.	LENGTH--CW.
MULTIPLIER--X1.	HORIZONTAL DISPLAY--MAIN SWEEP NORMAL.

a. Display about 2 cm of vertical deflection from calibrator, setting Main Sweep STABILITY for stable trace. Observe that READY lamp is on. Now switch HORIZONTAL DISPLAY to MAIN SWEEP DELAYED position. The trace should no longer appear, and the READY lamp should be extinguished. If now you operate the RESET MAIN SWEEP button, you should observe a single trace displaying the calibrator waveform across the screen. The trace should not recur until the RESET MAIN SWEEP button is again operated. Operate the button several times to assure that reliable operation of the sweep is obtained.

b. Next, remove the calibrator signal by breaking the connection at the plug-in INPUT connector. Operate the RESET MAIN SWEEP push button. The READY light should now glow steadily. Apply calibrator signal by making a connection at the plug-in INPUT connector. This should result in a single trace across the screen, displaying the calibrator signal. The trace should not recur, and the READY light should now be extinguished. Repeat this operation several times to assure consistent operation.

46. To check neons and scale illumination.--With the HORIZONTAL and VERTICAL POSITION controls, move the trace off the screen--both up and down, and right and left. Check that the appropriate neon directional indicators light up in each case. Then bring up the SCALE ILLUM. control, and check that it provides control of the graticule scale illumination. See that the lamps associated with this circuit are positioned into the subpanel and panel by the proper amount and are firmly mounted.

47. To check dual-trace operation.--With the sweep in a free-running condition, observe that alternate-trace operation occurs with the TIME/CM switch in the 10-millisec position and with the 53C MODE switch in the ALTERNATE SWEEPS position. Recheck with the TIME/CM switch in the 0.1 μsec position.

48. To check CRT cathode input circuit.--Get a stable display of calibrator signal with about 4 or 5 cm of vertical deflection. Remove the jumper connecting CRT CATHODE to GND, at back of oscilloscope. Connect VERT. SIG. OUT to the CRT CATHODE terminal. If the INTENSITY control is not set too high, a very noticeable decrease in brightness of the top of the square wave, and a corresponding increase in brightness at the bottom, should occur.

Now replace the jumper between the CRT CATHODE terminal and ground.