

TEK MP SPEC 1A  
JUNE 11, 1962



## TEKTRONIX SPECIFICATIONS

TYPE 945 AND TYPE RM945 OSCILLOSCOPES

TYPE ML AND TYPE MC PLUG-IN

PREAMPLIFIERS

## SECTION 1

### 1.1 GENERAL

The Tektronix Type 945 Oscilloscope, Type ML Plug-In Preamplifier, and Type MC Plug-In Preamplifier are militarized versions of the Type 545 Oscilloscope, Type I, Fast-Rise Plug-In Unit, and Type 53-54C Dual Trace Plug-In Unit. The Type RM945 is a rack-mounted configuration of the Type 945. They are designed to meet MIL-T-945A environmental specifications and are manufactured to most MIL-T-945A parts, materials, and process specifications. Where a deviation exists, the intent of the specification has been met by performing in accordance with the required environmental tests.

MIL-T-21200 and MIL-E-16400 are general specifications similar to MIL-T-945A. Many portions of these specifications are applicable to the Types 945, RM945, ML, and MC.

In addition to the Type ML, Fast-Rise, Plug-In Unit and Type MC, Dual Trace, Plug-In Unit, any Tektronix Type A to Z, Plug-In Unit can be used in the Types 945 and RM945. This feature extends the signal-handling versatility of these instruments during operation in normal environments.

### 1.2 STANDARD ACCESSORIES

- 2 - 10 $\times$  attenuator Type 16945 probes (42") with tips, holder and ground leads.
- 2 - Coaxial cable, RG58C/U, 50 $\Omega$ , 24", BNC.
- 2 - Binding Post Adapters UG 1090/U, (spec. scale), BNC.
- 1 - Green light filter.
- 1 - Instruction manual.

### 1.3 ADDITIONAL ACCESSORIES

The Type 945 can be supplied with front and rear protective panel covers in which accessory items and instruction manual are stored. The following are supplied in addition to the standard accessories when panel covers are provided:

- 1 - Coaxial cable, RG58C/U, 50 $\Omega$ , 48", BNC.
- 2 - Adapters, Conn., UG 273/U, BNC jack, UHF plug.
- 2 - Adapters, Conn., UG 274/U, BNC tee.
- 2 - Adapters, Conn., UG 914/U, BNC straight.
- 2 - Adapters, Conn., UG 255/U, BNC plug, UHF jack.
- 2 - Alignment tools.
- 1 - Screwdriver.
- 5 - Allen Key Wrench - one each - #4, #8,  $2/32$ ,  $3/64$ ,  $1/4$ .

## SECTION 2

### 2.1 ELECTRICAL-ENVIRONMENTAL

The following specifications are set forth to describe the operations of the Tektronix Type 945 and Type RM945 Oscilloscope and Type ML and Type MC, Plug-In Preamplifier combinations.

Any reference to the instrument or specimen, indicates either the Type 945 or Type RM945 in combination with either Type ML or Type MC Preamplifier, unless an exception is noted.

The electrical requirements embody the following environmental tests: Storage, Temperature, Altitude, Water, Drip, Primary Power Frequency, Humidity, Fungus, Vibration, Shock, and Radio Interference. If no statement is made to modify a requirement for any of these environments, it may be assumed the requirement will remain unchanged after or during the environmental test, which ever is applicable.

Tests and measurements are performed according to sections 4 and 5.

Characteristics	Requirements
<b>ELECTRICAL</b>	
<b>VERTICAL DEFLECTION</b>	
Type MC	Dual Channel Plug-In Preamplifier
Deflection Factor	0.05 v/cm to 50 v/cm
Calibrated Range	0.05 v/cm to 20 v/cm in nine calibrated steps 1, 2, 5, 10 sequence
Variable Range	2.5 to 1 uncalibrated variable attenuator extends range to 50 v/cm
Absolute Accuracy	Adjustable to 0% error on front panel, at 0.05 v/cm
Attenuator Accuracy	$\pm 3\%$ from $-20^{\circ}\text{C}$ to $+55^{\circ}\text{C}$ , $\pm 5\%$ from $-40^{\circ}\text{C}$ to $-20^{\circ}\text{C}$ , $\pm 5\%$ after Vibration and Shock tests.
Attenuator Compensation	Within $\pm 1\%$
Frequency Response	DC to 24 Mc, $\frac{+3}{-0}$ Mc
Low-Frequency Response	DC coupled, no greater than 2.5% down from 1 kc to dc AC coupled, no greater than 10% down from 1 kc to 5 cps.
High-Frequency Response	No greater than 30% (3 db) down from 50 kc, $\pm 3$ Mc after Humidity, Fungus, Vibration, and Shock tests.
Risetime	15 nsec or less, at 0.05 v/cm
Transient Response	No greater than $\pm 1\%$ overshoot, ringing, etc., at 0.05 v/cm; $\pm 2\%$ , from $-40^{\circ}\text{C}$ to $-20^{\circ}\text{C}$ and as a result of Humidity test $\pm 3\%$ after Fungus, Vibration, and Shock tests.
Linearity	$\pm 2.5\%$ from 2 cm to 4 cm
Modes	Channel A, Channel B, Chopped, and Alternate
Input Impedance	1 meg $\pm 5\%$ , 20 pf $\pm 5\%$
Trace Drift	$\pm 1$ cm from $-20^{\circ}\text{C}$ to $+55^{\circ}\text{C}$ (Temperature test only)
Maximum Input Voltage	600 volts (dc + peak ac)

Microphonics	5 mm maximum during Vibration test only	Regulation	At line voltage limits of 103.5 and 126.5, the vertical deflection will change no greater than 1.5% (Reference: 115 v. line, .05 v/cm on both channels)
Channel Isolation	90 db minimum, with 1-kc Amplitude-Calibrator square wave, 80 volts, 20 v/cm and 0.05 v/cm.		

Characteristics		Requirements					
ELECTRICAL							
Type MI	VERTICAL DEFLECTION						
Fast-Rise Plug-In Preamplifier		X10 Gain AC					
Deflection Factor	DC		AC	X10 Gain AC			
Calibrated Range	0.05 v/cm to 20 v/cm in nine calibrated steps. 1, 2, 5, 10 sequence.		0.005 v/cm to 50 v/cm				
Variable Range	2.5:1 variable atten. extends range to 50 v/cm "uncalibrated"		0.005 v/cm to 2.0 v/cm in nine calibrated steps. 1, 2, 5, 10 sequence.				
Absolute Accuracy	Adjustable to 0% error, at maximum sensitivity						
Attenuator Accuracy	-3% from -20°C to +55°C, -5% from -40°C to -20°C, -5% after Vibration and Shock tests.						
Attenuator Compensation	Within +/- 1%						
Frequency Response	DC to 30 Mc +3 Mc -0	5 cps to 30 Mc +3 Mc -0	5 cps to 24 Mc +3 Mc -0				
Low-Frequency Response	No greater than 2.5% down from 1 kc to dc						
High-Frequency Response	No greater than 30% (3 db) down from 50 kc to 30 Mc, at 0.05 v/cm -3 Mc after Humidity, Fungus and Shock tests						
Risetime	12 nsec or less at 0.05 v/cm						
Transient Response	No greater than +/- 1% overshoot, roll-off or ringing at maximum sensitivity. -2% from -40°C to -20°C and as a result of humidity test; 3% after Fungus, Vibration and Shock tests.						
Linearity	-2.5% from 2 cm to 4 cm						
Trace Drift	-1 cm from -20°C to +55°C						
Microphonics	5 mm, Vibration test only						
Input Impedance	1 Megohm, +/- 5%, 20 pF +/- 5%						
Maximum Input Voltage	600 volts, dc plus peak ac						
Regulation	At line voltage limits of 103.5 and 126.5, the vertical deflection will change no greater than +/- 1% (Reference: 115 v. line, at 0.005 v/cm)						

PROBE P6945, 42 INCH, WITH 5 INCH GROUND LEAD

Attenuation Ratio	10:1, +5%	
Frequency Response	MC Preamplifier High Frequency  dc to 22 Mc, +3 -0  as a result of Humidity, Fungus, Vibration, and Shock tests. High-frequency response no greater than 30% (3 db) down from 50 kc.	ML Preamplifier High Frequency  dc to 27 Mc, +3 -0 Mc X1  5 cps to 22 Mc, +3 -0 Mc X10  +3 Mc as a result of Humidity, Fungus, Vibration and Shock tests. High-frequency response no greater than 30% (3 db) down from 50 kc.
Risetime	Low Frequency dc coupled no greater than 2.5% down from 1 kc to dc  ac coupled no greater than 2.5% down from 1 kc to 5 cps	Low Frequency dc coupled no greater than 2.5% down from 1 kc to dc  ac coupled no greater than 40% rise from 100 cps to 5 cps
Input Impedance	MC Preamplifier 16 nsec or less	ML Preamplifier 14 nsec or less at 0.05 v/cm ac or dc. 16 nsec at 0.005 v/cm X10 gain ac
Maximum Input Voltage	10 megohm ±5%, 10 pf ±5%	600 volts (dc + peak ac) (Derating is necessary above 5 Mc. See probe derating specification).

Voltage Range	Amplitude Calibrator  0.2 mv to 100 v pk-pk. 1, 2, 5, 10 sequence.	Trigger Level  External AC, AC LF REJECT, DC and AUTO. ±0.5 v to ±50 v  Internal AC and AC LF REJECT 2 mm or less DC and AUTO 5 mm or less HF SYNC 30 Mc or greater, (2 cm deflection and 2 mm maximum horizontal jitter.)
Accuracy	±2% from -40°C to +55°C ±4% from +55°C to +71°C	
Frequency	1 kc ±40% square wave	
HORIZONTAL DEFLECTION		
Time/cm Range	Main Sweep  0.02 μsec/cm to 12 sec/cm 0.1 μsec/cm to 5 sec/cm in 24 calibrated steps. 1, 2, 5, 10 sequence. Uncalibrated vernier extends range to 12 sec/cm.	Trigger Input Impedance  1 megohm ±20% 50 pf maximum capacitance, depends on control position.
Accuracy	±3% from -20°C to +55°C ±5% from -40°C to +71°C ±5% Vibration and Shock	Single Sweep  Manual or electronic reset. Electronic reset is obtained by use of the delaying sweep with external trigger.
Sweep Expansion	X5 ±3% from -20°C to +55°C, ±5% from -40°C to +71°C. Extends range to 0.02 μsec/cm	Delaying Sweep  2 μsec/cm to 10 msec/cm in 12 calibrated steps: 1, 2, 5, 10 sequence. ±3% from -20°C to +55°C ±5% from -40°C to +71°C ±5% after Vibration and Shock tests

Trigger Level	1 volt to -50 volts	Volts, pk-pk	2, +50%, per cm of vertical deflection.
Jitter	1/20,000 at 1 msec/cm, (5 mm at 1000 expansion using Delay Time Multiplier and Main Sweep Display).	Frequency Response	20 cps to 4.5 mc. No greater than 30% (3 db) down, 50 kc reference.
Sweep Length	Continuously variable from 4 cm to 10 cm $\frac{+1}{-0}$ cm.	<b>POWER SOURCE</b>	
Variable Time Delay			
Delay Time Range	1 $\mu$ sec to 100 msec 2 $\mu$ sec to 10 msec in 12 calibrated steps; 1, 2, 5, 10 sequence Calibrated 10 turn vernier/multiplier extends range to 1 $\mu$ sec and 100 msec.	Regulation	115/230 v $\pm 10\%$ , 1 $\phi$ , 50 to 400 cps $\pm 10\%$ , 700 watts maximum At voltage limits 103.5 and 126.5, no greater than the following change from 115 v line will be observed: Amplitude calibrator, $\pm 0.5\%$ at 100 v Time Base, $\pm 0.75\%$ , Main and Delaying Sweep at 1 msec/cm
Accuracy	$\pm 1\%$ from -20°C to +55°C $\pm 2\%$ from -20°C to 0°C on 2, 5, 10 ms/cm only $\pm 3\%$ from -40°C to +71°C Incremental 0.2% from 0°C to +71°C at 500 $\mu$ sec; 0.3% from -40°C to 0°C.	<b>CRT DISPLAY</b>	
Horizontal Amplifier			
External Input	DC Coupled	CRT	T945P2
Deflection Factor	Continuously variable from 0.2 v/cm or less, to 10 v/cm or greater, utilizing 5X magnifier.	Accelerating Potential	10 kv
Attenuator Accuracy	X10 $\pm 3\%$ from -40°C to +55°C	Useful Scan	4 cm by 10 cm
Attenuator Compensation	Within $\pm 3\%$ in X1 and X10, at maximum variable-gain	Visual Writing Rate	Visible trace in darkened room with no brightened spot at start of sweep. Sweep at 0.02 $\mu$ sec/cm, 10 cps trigger rate.
Frequency Response	DC to 1 mc at maximum gain. High-frequency response no greater than 30% (3 db) down from 1 kc. Low-frequency response no greater than 3% down from 1 kc to dc.	Geometry	No greater than 1 mm of tilt or bowing.
Input Impedance	1 meg $\pm 5\%$ , 47 pf $\pm 5\%$	Focus	Horizontal: 1 mm markers distinguishable over 8 cm. Vertical: with a 1-line/0.5 mm raster, distinguishable lines can be observed over entire 4 cm of vertical deflection, with nominal intensity.
<b>OUTPUT SIGNALS</b>			
Volts, pk-pk	+Gate Main Sweep 25, $\pm 50\%$	Cathode Modulation	Intensity modulation can be obtained with 15 v $\pm 5$ v pk-pk.
	Sawtooth Main Sweep 165, $\pm 20\%$		
Volts, pk-pk	Delayed Trigger 7, $\pm 50\%$		
	+Gate Delaying Sweep 20, $\pm 50\%$		
Volts, pk-pk	Vertical Signal Out		

## 2.2 ENVIRONMENTAL

### 2.2.1 Storage:

As a result of preconditioning test Para. 4.4.1 of MIL-T-945A, +85°C, -65°C, 50,000 ft., there will be no visible damage or electrical malfunction. Adjustments may be performed if necessary to meet required accuracies.

### 2.2.2 Temperature:

Following Para. 4.4.4 of MIL-T-945A, -40°C to +85°C, the instrument will perform to the limits indicated in the individual characteristic requirements.

Maximum continuous operating temperature is +55°C for all rated accuracies. Operation from +55°C to 71°C is limited to one hour. The

amplitude calibrator, main sweep and delaying sweep, and time delay have specific tolerances up to  $+71^{\circ}\text{C}$ . Other characteristics will deteriorate an unspecified amount, depending on the length of time and how high above  $+55^{\circ}\text{C}$  the operation takes place.

Overheat warning light turns on at  $+59^{\circ}\text{C}$ ,  $\pm 3^{\circ}\text{C}$ . The thermal cut-off functions at  $+75^{\circ}\text{C}$ ,  $\pm 3^{\circ}\text{C}$ , for complete shut-down.

\* see Para. 3.1 Ventilation.

Minimum operating temperature is  $-40^{\circ}\text{C}$ .

#### 2.2.3 Altitude:

The instrument is capable of operating up to 20,000 ft. altitude with the maximum continuous operation temperature reduced to  $+50^{\circ}\text{C}$ . Test is performed according to Para. 4.4.4 of MIL-T-945A with 20,000 ft. altitude, instead of 10,000 ft.

#### 2.2.4 Water Drip:

The enclosure test is performed to meet Para. 5.2.3 of MIL-STD-108D, as called out in Para. 4.4.8 of MIL-T-945A; a stream of water directed at an angle of  $15^{\circ}$  from vertical, from a nozzle 3' above specimen, 1 ft. head, all surfaces for a period of 5 minutes. The instrument will meet all electrical specifications as indicated in individual characteristic requirements. Minor water entry will be tolerated.

This requirement is not applicable to the Type RM945.

#### 2.2.5 Primary Power Frequency

The instrument will meet electrical requirements at 50 to 400 cps  $\pm 10\%$ . Maximum waveform distortion 1%.

#### 2.2.6 Humidity:

Para. 4.4.2 of MIL-T-945A stipulates MIL-STD-170, 10 day Humidity test. ( $+18^{\circ}\text{C}$  to  $+65^{\circ}\text{C}$ , 90% to 98% relative humidity.) The instrument will perform to the limits indicated in the individual characteristic requirements as a result of this test.

#### 2.2.7 Fungi:

The instrument is placed in a Fungus test chamber 28 days as described in Para. 4.4.3 of MIL-T-945A,  $+30^{\circ}\text{C} \pm 5^{\circ}\text{C}$ , 90 to 100% R.H. After 48 hours drying at room conditions, all electrical specifications are met, modified as indicated in the individual requirements.

#### 2.2.8 Vibration:

Para. 4.4.5 of MIL-T-945A requires:

10 to 33 cps 0.06" pk-pk, 15 min, cycling in each of three major axes. 10 to 55 cps 0.03" pk-pk, 15 min, cycling in each of three major axes. Also, 3 min. at each of four most severe resonant points.

The instrument will meet these requirements. It is energized with all circuits functioning. There will be no intermittent or erratic behavior of display. Visible breakage, loosening of parts, excessive wear, or fatigue will not be permissible. All electrical specifications are met after the test, modified as indicated in the individual characteristic requirement.

The Type RM945 is mounted in a sufficiently rigid fixture which simulates a rack.

#### 2.2.9 Shock:

The instrument will meet the 400 lb. hammer drop test of MIL-T-945A, Para. 4.4.6, a total of nine blows:

Back and side, 1, 2 and 3 feet; top, 2, 3 and 4 feet.

Specimen is energized. Minor damage is permissible. After the test, the instrument will meet all electrical specifications as modified in the individual requirements.

The Type RM945 is mounted in a sufficiently rigid fixture which simulates a rack.

#### 2.2.10 Radio Interference:

The Types 945 and RM945 oscilloscopes and Type MI, and MC preamplifiers meet limits of Mil-I-16910A, Mil-I-26600, Mil-I-11748B for broadband radiated interference from 14 kc to 1000 Mc, and broadband conducted interference from 150 kc to 100 Mc. It also meets susceptibility test of Mil-T-945A, Para. 3.4.3.1.2, 1 mv, 50 kc to 400 Mc.

\* This requirement is not necessarily applicable to the Type RM945 in the side-cooling configuration, with the left cabinet side removed. Interference will depend on the individual installation.

#### 2.2.11 Salt Spray:

Parts are finished so there will be no destructive corrosion after 100-hour salt-spray test according to Fed. Std. 151, Para. 3.35, MIL-T-945A.

### SECTION 3

#### 3.0 MISCELLANEOUS

##### 3.1 Ventilation

Safe operating temperature is maintained by filtered, forced-air ventilation. For the Type 945, a minimum of 2" of unobstructed clearance around the instrument is recommended for adequate ventilation. For the Type RM945, some deviation from specified temperature limits may be encountered when mounted in a rack enclosure because of recirculation and adjacent equipment. With no adjacent equipment, continuous operation can be expected if the input air does not exceed  $55^{\circ}\text{C}$  and there is adequate air flow, 225 to 250 cfm.

For side cooling, (left side of cabinet removed) 250 to 350 cfm is required, depending on direction and uniformity of the air flow. In this cooling configuration, the air filter is removed, a cover plate is placed over the normal air input hole, and the fan remains operating.

### 3.2 Finish

#### TYPE 945

Military light-gray, semi-gloss baking enamel per MIL-F-14072, on cabinet and front panel. Photo-etched lettering.

#### TYPE RM945

Same as above except cabinet is yellow chrome conversion coating.

### 3.3 Dimensions

#### TYPE 945

18.2 in. high; 13.4 in. wide; 25.3 in. deep—without panel covers

18.4 in. high; 13.8 in. wide; 26.4 in. deep—with panel covers

#### TYPE RM 945

17.5 in. high, 19 in. wide, 24 in. deep behind panel, 26.6 in. overall depth

The maximum front-panel diagonal length, with trim-strips removed, is 24.7".

Fits a 19" rack, Mil-Std-189

### 3.4 Weight

Type 945 without preamplifier	80 lbs.
Type RM945 without preamplifier	111 lbs.
Type ML preamplifier	4.8 lbs.
Type MC preamplifier	5.0 lbs.

### 3.5 Power Cable

#### TYPE 945

Permanently attached three-wire, with a MIL-C-3767/4 plug.  
(2 or 3 prong)

#### TYPE RM945

A jumper power cord is attached to the frame of the instrument for operating equipment when pulled out on slides. Normal power connections are made directly to terminal strip on back of cabinet.

### 3.6 Connectors

All input and output signal jacks are of the BNC type.

### 3.7 Warm-up Time

20 min. for rated accuracies.

## SECTION 4

### 4.0 METHOD OF MEASUREMENT OF ELECTRICAL PERFORMANCE

The uniqueness of an oscilloscope as a measuring instrument requires special techniques to specify and measure some of its performance characteristics. Proper methods of measurement are essential in expressing the instrument's abilities. In an effort to assist the user, the following techniques are presented.

The oscilloscope is a three dimensional device X, Y, and Z. The X and Y axes convey precise quantitative information. Any specification concerning measurements along these axes is considered of primary importance. Other characteristics describe the performance of the oscilloscope but do not contribute much to the preciseness of measurement. For this reason the X-Y calibration is discussed in greatest detail.

Environmental conditions should be established before proceeding with measurements. Standard conditions are: +25°C ±5°C, 30 to 60% R.H., 0 to 10,000 ft. altitude, 115 volt line, 60 cps. A 20 minute warm-up is allowed for circuit stabilization.

### 4.1 VERTICAL DEFLECTION

#### 4.1.1 Deflection Factor:

This characteristic is measured by applying an approximate 1-ke square wave, from a precision voltage calibrator, to the input connector of the oscilloscope. Nominally, 2 divisions of deflection are used so that linearity is not involved in correlation of measurements. A ±3% tolerance on the attenuator means, with a ±½% voltage calibrator, the observed variation can be no greater than ±2½%, or 0.45 mm out of 20 mm. The procedure for checking the oscilloscope is to adjust the amplifier to the indicated deflection factor at maximum sensitivity, or make note of its deviation before measuring the other attenuator positions. Optical magnification may be used to obtain better resolution.

#### 4.1.2 Attenuator Compensation:

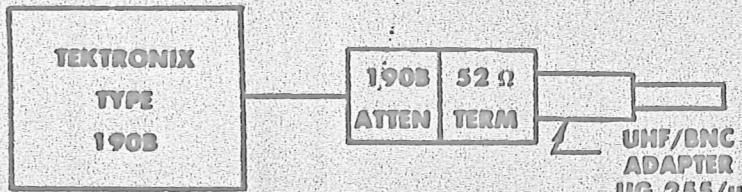
The attenuator compensation is observed by means of a square-wave test signal with an approximate frequency of 1 ke and a risetime of 1 to 5 µsec.

#### 4.1.3 Linearity:

Linearity is measured by applying a signal of 2 cm and then increasing it by a factor of precisely 2 (4 cm display). The amount of deviation from 4 cm is a measure of the linearity of the vertical-deflection system. 1 mm in 40 mm is considered 2.5% non-linearity.

#### 4.1.4 Frequency Response:

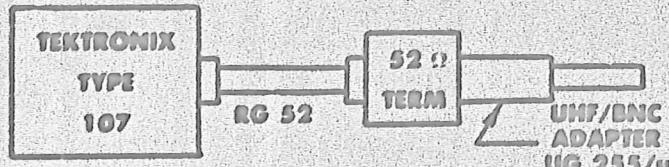
Frequency response is determined with a constant-output signal generator, Tektronix Type 190B or equivalent. This instrument operates from 50 kc to 50 mc. Its constant output is set by a double-peak rectifier system that, by nature of the circuit design, remains very constant over its frequency range at the rectifier sampling point. The actual frequency response is influenced by the resonance of the input reactance of the oscilloscope. Any type of adapter, or part, that is placed between the generator and the instrument will have some effect on the results. The only way to obtain consistent results is to use the same "setup" each time a measurement is made.



The resonant effects are most apparent at 30 mc, which is the bandwidth of the Type 945 with a Tektronix Type ML Preamplifier. Bandwidth with the Type MC Preamplifier is rated at 24 mc, so the problem is less severe; however, the effect should be considered whenever measuring bandwidth at these frequencies. Having made the proper connections to the oscilloscope, a 50 kc signal level is set which provides 4 cm of deflection. The frequency is increased until 2.8 cm is observed (30% down or 3 db). The response at intermediate frequencies is not measured because normal transient adjustments with a square wave result in a midband response that is very flat. At the lower end of the spectrum, the measurement is made by introducing a 1 kc square-wave signal from the square-wave voltage calibrator, then noting the deviation when the calibrator is switched to DC.

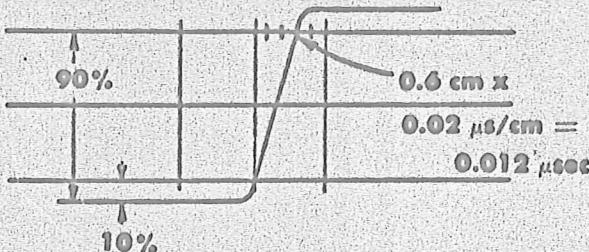
#### 4.1.5 Transient Response:

The overshoot and ringing of a step function is very difficult to measure because of resolution. Normally, specifications are written around a figure of  $\pm 1\%$ . Qualitatively, a very "poor looking" waveform can still be within specifications. Less than a  $\pm 1\%$  is difficult to read because a typical trace width is 0.4 mm or 1% of 4 cm. Here again, optical magnification is helpful.



Risetime can be measured with good accuracy by using a Tektronix Type 107 SQUARE WAVE GENERATOR, properly terminated. The 10% and 90% levels are the points between which the measurement is made.

This can be done conveniently by adjusting the amplitude of the step waveform to exactly 2.5 cm, then positioning the display so the two 10% areas are equally divided above and below the 2 cm marks. The 10% crossing point is positioned on a major vertical graticule line.



The point where the 2-cm line and the waveform intersect results directly in a risetime reading. The risetime of a square-wave generator may be significant in the following equation if it is longer than the typical 3 nsec of the Tektronix Type 107.

$$RT = \sqrt{(rt_1)^2 + (rt_2)^2}$$

Where RT is value observed on the oscilloscope

$rt_1$  = risetime of the generator

$rt_2$  = risetime of the scope amplifiers

The oscilloscope time base should be within calibration specifications before risetime measurements are made.

#### 4.2 AMPLITUDE CALIBRATOR

The calibrator provides an approximately 1 kc square wave, with an amplitude that is within 2% of the value indicated. Its accuracy is measured by applying a calibrating signal to a mixing-type voltage calibrator, and is compared either on another oscilloscope or the one under test. Again, the deviation on any position cannot exceed  $\pm 1\%$  to be consistent with the  $\pm 1\%$  tolerance of the reference voltage-calibrator. If calibration curves are used in conjunction with the reference calibrator, accuracies to  $\frac{1}{4}\%$  may be obtained. A 4 cm display is used to provide maximum resolution.

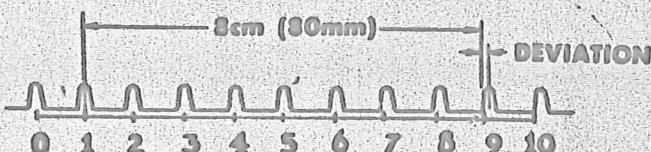
#### 4.3 HORIZONTAL DEFLECTION

##### 4.3.1 Main Sweep:

A time mark generator, Tektronix Type 180A or equivalent, is employed for "timing" both sweeps. Since rated accuracy of 0.001% is much greater than that of the time bases being measured, no allowance need be made for instrument error. The various definitions of

Timing accuracy and linearity prescribe that a common method of measurement be used. A timing display is set up so that a timing "pip" corresponds to each major division of the graticule.

The percent deviation is read as the difference between the ninth cm division and the corresponding marker.



The first and last cm of a 10 cm display are less accurate because of CRT linearity, sweep-amplifier linearity, and focus. This is the reason for the timing method. However, full accuracy exists if time measurements are performed by positioning the start of the sweep away from the described edge-distortion.

The 5-x magnifier accuracy is checked in three areas—start, center, and end of the trace. Deviation is expressed as mm in 80 and is in addition to any observed deviation in the unmagnified time base. The magnifier is checked at the 1 msec/cm and 0.1  $\mu$ sec/cm positions of the Time/cm switch. The first 3 cm of the trace at 0.1  $\mu$ sec X5 are not included in the timing.

#### 4.3.2 Delaying Sweep:

Time/cm is measured in the same manner as the main sweep. The delay time and incremental accuracies are measured by means of the DELAY TIME MULTIPLIER dial. A delaying-sweep display is obtained with main-sweep brightening. Main-sweep time/cm is chosen to be at least 1/10 that of the delaying-sweep time base. The timing check is made in the "Main Sweep Delayed" position of the HORIZONTAL DISPLAY switch. Delay Time range accuracy is the deviation in a total of 800 minor divisions, from approximately 1.00 to 9.00 on the DELAY-TIME MULTIPLIER dial.  $\pm 1\%$  means  $\pm 8$  divisions in 800.

Incremental delay-time accuracy is the percent deviation from periodic major divisions. Since the beginning and ending major divisions are seldom even numbers (1.00 & 9.00), the procedure for obtaining percentage deviation is a little involved. Essentially, it is a matter of first determining the periodic major divisions and then calculating the deviation that exists at each setting of the dial. This is probably best explained by an example:

Readings obtained from DELAY-TIME MULTIPLIER dial.

1.000	4.990
1.995	5.980
2.995	6.970

$$\begin{array}{r} 3.990 \quad 7.955 \\ 8.960 \quad 8.960 \\ 8.960 - 1.000 = 7.960 \text{ or } 796.0 \text{ minor divisions.} \\ \frac{796.0}{8} = 99.5 \text{ minor divisions between each periodic major division for perfect linearity.} \end{array}$$

Periodic Major Divisions	Delay-Time Multiplier Readings	Deviation in Minor Divisions
1.000	1.000	0
1.000 + .995 = 1.995	1.995	0
1.995 + .995 = 2.990	2.995	+ .5
2.990 + .995 = 3.985	3.990	+ .5
3.985 + .995 = 4.980	4.990	+ 1.0
4.980 + .995 = 5.975	5.980	+ .5
5.975 + .995 = 6.970	6.970	0
6.970 + .995 = 7.965	7.960	- .5
7.965 + .995 = 8.960	8.960	0

Each deviation at the major dial-points is within  $\pm 1.6$  minor divisions or .2% of 800.

#### 4.3.3 Jitter:

Jitter is measured by setting up the delaying sweep in the 1 msec/cm position and the main sweep to 1  $\mu$ sec/cm, free run. This effectively gives a 1000/1 magnification. In the main-sweep delayed position, 5 mm represents 1 part in 20,000. The first major division and ninth major division of the delay-time multiplier-dial are check points.

#### 4.3.4 External Sweep Input:

When measuring the deflection factor of the horizontal amplifier, the signal is connected to the External Sweep Input and the External Trigger Input, Main Sweep. The Main-Sweep Sawtooth Out is connected to the Vertical Input. Vertical gain is adjusted for a convenient number of cycles of the test signal. Magnifier is in the X-5 position. The resulting display is a triggered sweep in the vertical direction.

### 4.4 CATHODE RAY TUBE

#### 4.4.1 Visual Writing rate:

Visual writing rate is measured by externally triggering the main sweep at a repetition rate of 10 cps. With the time base at 0.02  $\mu$ sec/cm, a trace should be visible in a darkened room. The intensity, focus, and astigmatism controls are adjusted for a sharp trace, with no brightened spot at the start of the sweep.

#### 4.4.2 Focus:

**4.4.2.1 Vertical direction:** Obtain a raster of 2 horizontal lines/mm by connecting Sawtooth Main Sweep to Vertical Input. Delaying-sweep is free run at 10  $\mu$ sec/cm, main-sweep is free run at 1 msec/cm and the horizontal display is in

"Delaying Sweep" position. Adjust the number of horizontal lines to 2/mm with the volts/cm variable control. Optical magnification may help to adjust properly. Nominal intensity is used.

**4.4.2.2 Horizontal direction:** The time-mark generator signal is displayed to give a marker/mm with at least 4 cm amplitude.

In both measurements, focus is evaluated by being able to distinguish separate lines over the specified length.

#### 4.5 Instrumentation for Measuring Oscilloscope Performance:

In any type of measurement, some system of referring to a fundamental standard is necessary. Each of the aforementioned instruments can be calibrated to a primary standard.

The precision square-wave voltage calibrator is the type which can mix an incoming ac or dc signal with its output. This is accomplished by means of an electromechanical switch at a 60 cps rate. No error is introduced by this mixing method; therefore, direct comparison can be made with a dc secondary standard. The calibrator also provides a dc-output voltage which enables the 1 kc to dc frequency-response measurement to be performed simply.

The TYPE 190B CONSTANT-AMPLITUDE VOLTAGE GENERATOR is checked for frequency against WWV. The constant-amplitude output is more difficult to ascertain. A peak-to-peak detection device is required which has a frequency response known to be absolutely flat, and sensitive enough for the low signal-level. A peak-to-peak rectifier h.f. voltmeter can be used; however, its only reference is the rectifier system and measuring techniques involved. Careful checks of the Type 190B, by means of VHF detection techniques, indicate it does meet the called out constant-voltage requirements.

Risetime of the Type 107 Square-Wave Generator is verified by means of an oscilloscope time base. The transient overshoot, etc., is observed by use of a wide bandwidth oscilloscope, or by connecting the output directly to an oscilloscope's crt deflection plates.

The 1 usec output of the Type 180A sweep timing generator is checked to WWV. Proper dividing or multiplying is checked on an oscilloscope.

## SECTION 5

### 5.0 ENVIRONMENTAL TEST METHODS

The conclusions from environmental tests are influenced by the manner in which the tests are performed. The methods described should be followed whenever testing for this specification so consistent results can be attained.

The implied sequence of tests of MIL-T-945A indicates the temperature-altitude tests are performed after the humidity and fungus tests. The temperature-altitude is a reversible non-destructive test, whereas the humidity, fungus, vibration, and shock tests are accelerated and deteriorating in nature. Non-destructive testing should be performed first. In this way, maximum limits can be called out that are meaningful in practice. Also, measuring to limits rather than percentage-changes results in less error, less misinterpretation, and less labor.

The water-drip and variable-frequency tests are also performed before humidity, fungus, vibration and shock tests because they are non-deteriorating. The radio interference test is non-destructive. The end result is not dependent on oscilloscope calibration; therefore, the sequence of testing is optional.

Unless otherwise stated, electrical measurements are performed at standard conditions: +25°C ±5°C, 30 to 60% R.H., 0 to 10,000 ft. altitude, 115 volts line, 60 cps. A 20 minute warm-up is allowed for circuit stabilization.

The panel protecting covers, with accessories, are placed in various chambers, detached from the oscilloscope. The probes are checked in conjunction with the oscilloscope undergoing test.

#### 5.1 STORAGE

Temperature stabilization is determined by the transformer. Eight hours has been determined to be a practical limit. At simultaneous low-temperature and altitude, the 50,000 ft. altitude is held for the last hour of the cycle.

#### 5.2 TEMPERATURE-ALTITUDE

After 24 hours of drying at +55°C, any adjustments necessary to meet specifications are made to a specimen.

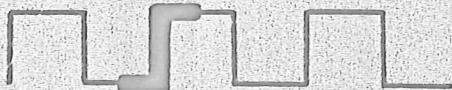
The specimen is placed in a temperature chamber with a fairly large volume (64 cubic feet). This will give reasonably typical cooling. Recirculation of exhaust air of the oscilloscope cooling system is minimized. During the high-temperature portion of the tests, the chamber circulating fan is turned off about  $\frac{1}{2}$  hour before taking readings. The chamber contains ports and a window so all measurements can be made from the outside. A minimum of 4 hours stabilization has been determined to be practical for this series of tests.

A complete check is first made at +25°C, then at 0°C, -20°C, and -40°C. After stabilization at +25°C, the oscilloscope is placed in an altitude chamber at +25°. Manipulation of controls is not practical. Only primary characteristics are checked. Frequency response is dependent on connections and is usually unaffected by altitude; therefore, it is not included in this test.

Deflection factor on both channels is checked at one time by placing the amplifier in the chopped

mode at 0.05 v/cm. The amplitude calibrator voltage is also brought out and checked in this first run. Altitude is held for 15 minutes and returned to ambient. The main sweep and delaying sweep are each checked at 1 msec/cm for 15 minutes. The entire procedure involves 45 minutes operation at specified altitude. After returning to ambient, a complete specification check is made. The oscilloscope is again placed in the large temperature chamber and stabilized at +55°C, after which complete specifications are measured.

For the +71°C test, the oscilloscope amplitude-calibrating signal is connected to the vertical input at 0.05 v/cm, chopped mode. The vertical signal-out is used to trigger the delaying sweep. The main sweep is set to free run at about 1/10th the rate of the delaying sweep. This gives a display which involves essentially every circuit in the oscilloscope and will immediately indicate a catastrophic failure. This is termed the "self checking" mode.



The amplitude calibrator and sweep specifications are checked as indicated in electrical requirements. Operation is limited to 1 hour at +71°C.

The last measurements of this test are made at +25°C, after processing the oscilloscope through the +85°C non-operating cycle.

### 5.3 WATER DRIP

This test is performed by placing the test specimen on a cart that can be maneuvered in all positions to obtain a stream of water on every surface. The 1 ft. head of water is maintained by holding the level in a supply tank. The "domestic" nozzle is positioned at such an angle, 3° above specimen, that the stream hitting the instrument is approximately 15° from vertical. The front and rear protective-covers are in place during the test. The specimen is sprinkled continuously for 5 minutes. A complete electrical check is made to demonstrate that it was unaffected by the water exposure.

### 5.4 PRIMARY POWER FREQUENCY

Power frequency is not generally considered an environmental condition. However, it is a parameter that requires thorough checking. A complete set of measurements is recorded at 45 cps and 440 cps. Close attention should be given to waveform distortion. A 1% value, as measured on an audio distortion meter, has proven to be a practical limit.

### 5.5 HUMIDITY

MIL-STD-170 calls out a test measurement every 24 hours, and MIL-T-945A specifies test

measurements not more than 5 minutes after applying power. A full check of the oscilloscope can be completed in about 2 hours by a skilled operator. Therefore, only primary characteristics are checked after 5 minutes warm-up during 9 out of 10 half-cycle test periods. These are:

- Deflection factor at 0.05 v/cm, both channels, or 0.05 v/cm and 0.005 v/cm.
- High-frequency response
- Amplitude calibrator at 100 volts
- Main sweep 1 msec/cm
- Delaying sweep 1 msec/cm
- Time delay 500  $\mu$ sec

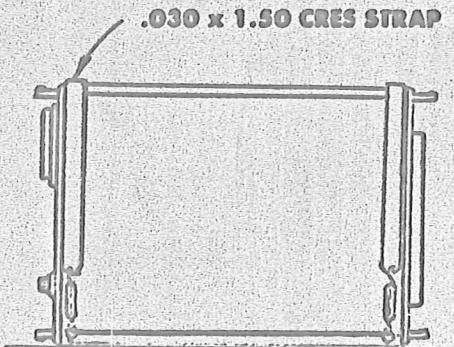
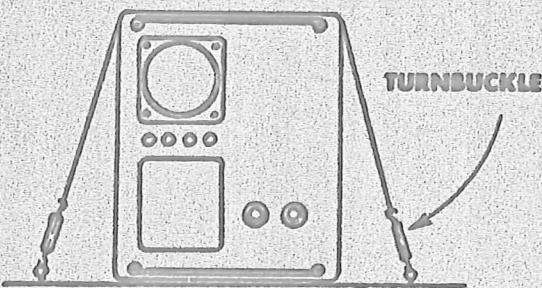
Since it is important to have the specimen go directly into fungus after humidity, a complete electrical specification check is made in the middle of the 5th cycle of humidity. The 10th check, at the end of the 5th cycle, is of primary characteristics only.

### 5.6 FUNGUS

All cabinet covers are removed and the instrument is inoculated with the fungi spores. After 28 days, the specimen is removed from the chamber and allowed 48 hours drying at room conditions. The fungus test is a long-term humidity environment that involves condensation. The intent of the specification is to determine the effect of fungus, not condensed water, hence the 2-day drying period. Inspection for fungus growth is performed immediately after removal from chamber.

### 5.7 VIBRATION

The oscilloscope is fastened to the vibration table in normal operating position by means of stainless-steel strapping and turnbuckles.



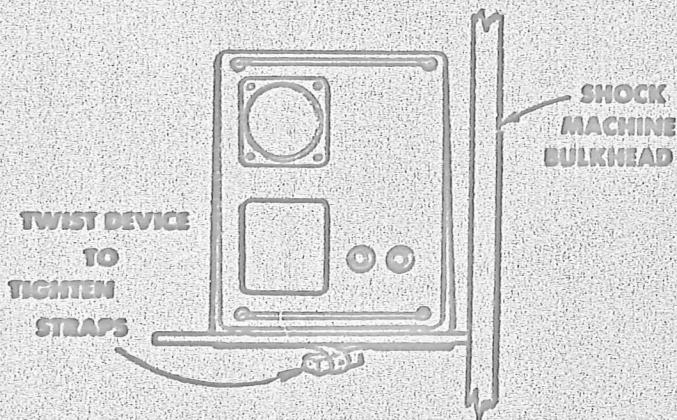
Cabinet sides and top are removed to allow observation. The panel covers and accessories are not included in this test. The table is capable of both horizontal and vertical motion so the specimen need be only rotated once in the horizontal plane to test along the three major axes. The oscilloscope is connected in the self-checking mode and is energized.

The RM945 is mounted in a sufficiently rigid fixture which simulates a rack. The fixture is fastened to the vibration table by clamps or steel straps.

In absence of severe resonant points, the specimen is vibrated for 3 minutes continuously, at 55 cps in each plane.

After the test, a complete electrical test is performed.

### 5.8 SHOCK



The oscilloscope is fastened to a bracket on the shock machine bulkhead so it remains in normal position throughout the tests. Heavy nylon or cotton straps are employed to hold the oscilloscope to the bracket. The cabinet sides and top are removed. The panel-covers and accessories are not included in the test.

The RM945 is mounted in a sufficiently rigid fixture which simulates a rack. The fixture is fastened to the shock machine bracket with heavy nylon or cotton straps.

The instrument is connected in the self-checking mode (energized) to detect any catastrophic failure. These connections also determine if the oscilloscope performs its principal functions per test requirements.

### 5.9 RADIO INTERFERENCE

The radio interference test of MIL-T-945A is somewhat unrealistic in several cases. Therefore, the oscilloscope is tested to meet three other specifications: MIL-I-16910A, MIL-I-26600, and MIL-I-11748B.

#### 5.9.1 Interference:

The sweeps are placed in free-run condition, the amplitude calibrator is set to 100 volts, and the type MC preamplifier is in the chopped mode. All BNC connections to the oscilloscope are shielded. At each check-point, the sweep-range switches and variable-multiplier controls are operated. Most interference is detected at fastest sweep rates.

#### 5.9.2 Susceptibility:

The BNC covers are in place and the amplifier is placed on 0.05 v/cm. (0.005 v/cm for Type ML.) The main sweep is operated through full range to try to synchronize with any interfering signal. An amplitude greater than 1 mm is considered an interference.

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