1502
TIME
DOMAIN
REFLECTOMETER

TEKTRONIX®

OPERATORS HANDBOOK

070-1790-00

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1502
TIME DOMAIN REFLECTOMETER OPERATORS MANUAL

Introduction

This manual is designed as an aid for field operation of the 1502, as a quick reference guide, and to be stored in the accessory compartment of the front cover. It is printed on waterproof paper and will not deteriorate when wet. Complete operating instructions, specifications, maintenance, and calibration procedures can be found in the 1502 Instruction Manual.

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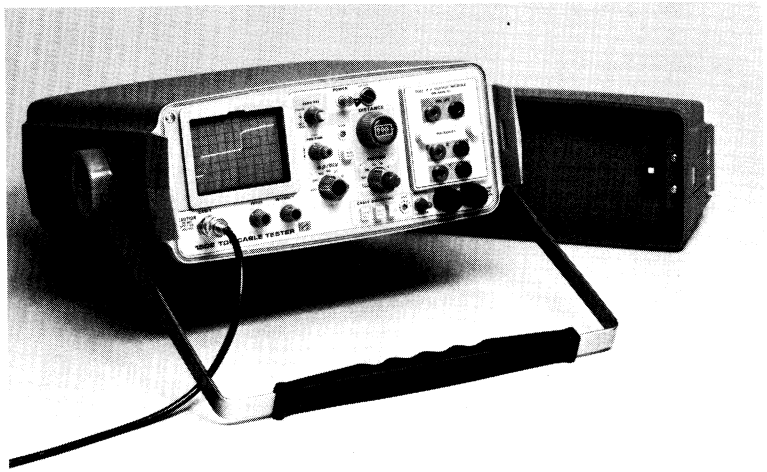

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Fig. 1-1. 1502 Time Domain Reflectometer.

SECTION 1
DESCRIPTION

The Tektronix 1502 is a portable, battery-powered Time Domain Reflectometer which uses radar principles to test cables and provide a visual display of cable faults. The test pulses are transmitted via the CABLE output jack. Reflections are received at the same jack and displayed on the Cathode-Ray Tube (crt).

The 1502 is constructed to meet the requirements of MIL-T-28800A for a Type II, Class 2, Style A instrument. Complete specifications are given in Section 1 of the 1502 Instruction Manual.

NOTE

All distances are shown in feet followed by metres in parenthesis. Metric units are not direct conversions from the measurements shown in feet, but represent the calibrated ranges of the metric option 1502.

1502 Calibrated distance controls allow an operator to examine up to 100 feet (25 metres) of cable with segments as small as 1 foot (25 cm) displayed horizontally across the 10-division crt screen. Low-loss cables as long as 2000 feet (500 metres) may be examined at 100 feet (25 metres) per division or 200 feet (50 metres) per division. The horizontal crt scale is calibrated directly in distance units from 0.1 foot (2.5 cm) per division to 200 feet (50 metres) per division in a 1-2-5 sequence (1-2.5-5 sequence).

A 3-digit, direct reading dial indicates the distance to any cable discontinuity when the dial is used to horizontally position the discontinuity's reflection to a crt reference line.

Vertical (Y-axis) deflection of the crt beam is proportional to the amplitude of the reflected signal plus the incident step. The vertical scale is calibrated in units of rho (ρ) of the transmitted pulse amplitude. For a definition of rho refer to Section 3 of this manual. The sensitivity scale can be selected in 7 calibrated steps from 5 mρ/div to 500 mρ/div.

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1502 The transmitted pulse is a step-signal having an amplitude of approximately 225 mV. The risetime of the pulse generator and the equivalent bandwidth of the deflection circuits provide a system reflected risetime of 140 ps or less. The displayed risetime of the incident edge of the step signal is 110 ps or less.

TABLE 1-1

Standard Accessories for the 1502

Accessory	Tektronix Part Number
1 TDR Slide Rule	003-0700-00
1 TDR Application Note #1	062-1538-00
1 Precision 50 Ω Cable	012-1482-00
1 50 Ω BNC Termination	011-0123-00
1 BNC Connector, Female-to-Female	103-0028-00

TABLE 1-1 (cont)

Accessory	Tektronix Part Number
2 Replacement Fuses (Front Panel)	
For 115 V ac Operation	159-0029-00
or	
For 230 V ac Operation	159-0054-00
1 Power Cord	161-0066-00
1 Viewing Hood	016-0297-00
1 Filter, Mesh (crt)	378-0055-00
1 X-Y Output Module	016-0606-00
1 Operators Manual	070-1790-00
1 Instruction Manual	070-1792-00

SECTION 2

OPERATING INSTRUCTIONS

A brief description of the purpose of each front panel connector, pushbutton, control, and screwdriver adjustment follows. A description of the controls of the plug-in modules is also included.

Front Panel Controls (See Fig. 2-1)

1. CABLE	Precision 50 Ω BNC connector; delivers 110 ps risetime pulse to test cable.
2. FOCUS	Controls sharpness of crt display.
3. INTENSITY	Controls brightness of crt display.
4. POSITION/FINE	Vertical position controls for crt display.

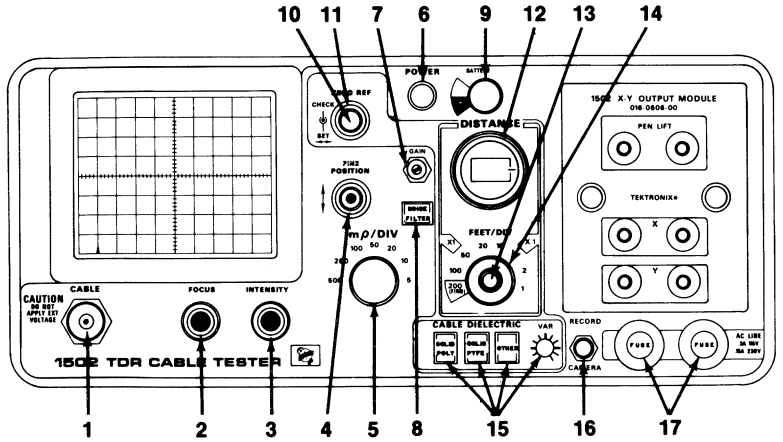

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Fig. 2-1. Front Panel Controls.

5. mρ/DIV — Selects vertical deflection factor (50 ρ/div to 500 mρ/div) in a 5-2-1 sequence.

6. POWER — Push-pull, off-on switch (pull for on). Does not affect battery charging circuit.

7. GAIN — Screwdriver adjustment to set gain of vertical amplifier.

8. NOISE FILTER — Reduces displayed noise. Display rate is reduced ≈10 times.

9. BATTERY METER — Indicates relative charge of power pack.

10. ZERO REF CHECK — Pushbutton. (When pushed, checks horizontal location of incident pulse on crt.)

11. ZERO REF SET — Horizontal pulse position control for crt display sets incident pulse edge to a vertical reference line of crt when DISTANCE dial is at 000 or ZERO REF CHECK button pushed.

12. DISTANCE — Indicates distance from 1502 to point on cable. Has 2 ranges: 100 feet (25 m) at X.1; or 1000 feet (250 m) at X1. Disabled when FEET/DIV (METRES/DIV) at 200 (FIND) (50).

13. X.1
X1 — Two-position switch for X.1 or X1 multiplier; affects both DISTANCE dial and FEET/DIV (METRES/DIV) control.

14. FEET/DIV (METRES/DIV) — Selects horizontal deflection factor:

X1	1—200 ft/div (25 cm—50 m/div)
X.1	0.1—20 ft/div (2.5 cm—5 m/div)

15. CABLE DIELECTRIC
SOLID POLY
SOLID PTFE
OTHER VAR — Three pushbuttons and a screwdriver adjust for selection of the proper velocity of propagation. VAR from 0.55 to 1.0 when OTHER is pushed (fully cw is for air dielectric). VAR control has reference marks every 30° to indicate relative propagation constants.

16. RECORD/CAMERA — Two-position lever switch: pushed up and then released, it initiates X-Y recorder or a chart recorder; pushed down, it floods crt during retrace for photography.

17. AC LINE FUSES — Protection for line power to battery charger circuitry (0.3 A fuses for 115 V ac, 0.15 A fuses for 230 V ac).

Plug-in Modules

1. X-Y OUTPUT MODULE — The standard plug-in module for the 1502. Used to drive an external X-Y chart recorder.

   X, Y, and PEN LIFT — Six front panel jacks used for driving external X-Y recorder (X jacks for horizontal drive, Y jacks for vertical drive), PEN LIFT jacks for pen control.

2. STRIP CHART RECORDER — An optional Tektronix chart recorder which replaces the X-Y OUTPUT MODULE.

   STYLUS POSITION — Screwdriver adjustment found on STRIP CHART RECORDER; adjusts stylus to the same level as the crt display.

Powering the 1502

The 1502 operates from the battery supply and can be used while it is charging from an ac source.

To operate the 1502 while charging, the battery pack must be installed, the power cord must be connected to the receptacle at the rear of the case and an ac power outlet, and then the front panel POWER switch, must be pulled to turn the unit on.

The battery charging circuits are factory wired for 115 V ac or 230 V ac if option 6 is ordered. See the 1502 Instruction Manual for conversion to 230 V ac. The unit will operate for a minimum of 5 hours (including 20 chart recordings) on a battery pack that is completely charged (at 25° C) at the start of operation. However, if a Tektronix Y-T chart recorder is used, the 5 hour operating time will decrease by about 3 minutes for each recording made beyond the 20 specified.

Operating the 1502

The front cover is removed by pulling up and in on the 2 release latches of the cover and pulling up on the cover. All necessary accessories are inside the front cover. The door to the accessories compartment can be unlatched by placing the index and middle fingers under the T-shaped knob and pressing the button with the thumb.

1. Pull POWER switch to turn on and set controls as follows: (see Fig. 2-2):

FOCUS	Midrange
INTENSITY	Midrange
ZERO REF	Fully cw
POSITION	Midrange
mρ/DIV	500
DISTANCE	000
FEET/DIV	1
(METRES/DIV)	(.25)
X1-X.1	X1
CABLE DIELECTRIC	SOLID POLY

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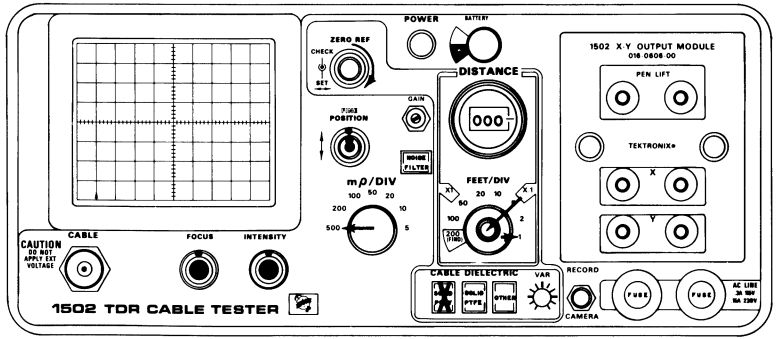

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Fig. 2-2. Test Set-up.

2. Adjust INTENSITY & FOCUS for a clear bright trace.

3. Adjust POSITION to set trace 2 divisions below horizontal center line.

4. Attach precision 50 Ω cable (012-0482-00) to CABLE connector.

5. Turn ZERO REF SET ccw until the incident pulse edge is located on a vertical reference line. The incident pulse edge is the initial rise of the step pulse. The vertical reference line may be any line you choose from the center line to the left side of the crt graticule. We have added an arrow in the second vertical line to indicate a commonly used reference line.

The reflected pulse from the open end of the 50 Ω cable should appear 3 horizontal divisions to the right of the reference line in the non-metric version only. The open end of the cable is indicated by the start of a second rise in the trace (see Fig. 2-3).

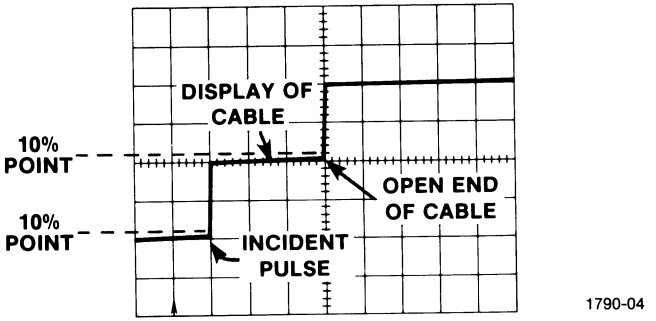

Fig. 2-3. CRT Display of Pulse.

6. Adjust ZERO REF SET throughout its range to see that the incident pulse edge can be set on any vertical graticule line. Set the incident pulse edge on the vertical reference line.

7. Set the DISTANCE dial to 050 and check that the top of the step (open cable reflection) is displayed.

8. Press the ZERO REF CHECK button and check that the incident pulse edge returns to the vertical reference line of the graticule. Reset DISTANCE dial to 000.

9. Change mρ/DIV to 50 and adjust POSITION so top of the incident pulse is on the horizontal center line.

10. Press NOISE FILTER and check for a reduction in displayed noise as well as reduction in scan rate. Reset mρ/DIV to 500, release (by depressing a second time) the NOISE FILTER button.

11. Press and hold the CAMERA switch. Note the crt display; the entire crt should be flooded on retrace to illuminate the graticule for photographic purposes. Release the CAMERA switch.

12. Lift up and hold the RECORD switch. Check that a bright spot appears at left edge of the crt.

13. Release the RECORD switch and note slow scan of the displayed waveform. When the scan is complete the 1502 will automatically return to its normal mode of scanning.

Connecting a Test Cable to the 1502

CAUTION

Do not connect live circuit cables to the input of the 1502. Voltages in excess of 5 V can damage the sampling gate or tunnel diode. If both the sampling bridge and tunnel diodes are destroyed at the same time, an improper use is indicated. If such simultaneous damage occurs, repair charges will be assessed to the customer regardless of the equipment warranty period.

Bleeding of cables before connecting them to the 1502 will remove static charge from the cable. The 50 ohm termination and BNC adapter supplied may be used to bleed any cable charge.

When testing antennas, be sure that you are not close to transmitters that can be keyed at the antennas receiving frequency. Keying of transmitters in close proximity can cause damage to the 1502.

Connect cables, to be tested by the 1502, to the BNC connector (CABLE) on the front panel. Although the 1502 is calibrated for 50 Ω, cables of any impedance may be tested and the only effect will be slightly increased ringing as the pulse starts down the cable. Table 2-1 lists optional connectors/adapters that can be used with the 1502. The paragraphs under "Evaluating a Discontinuity" in this section describe displays of different impedance changes (discontinuities) in a cable.

TABLE 2-1

Optional Connectors/Adapters for the 1502

Type	Tektronix Part Number
BNC, Female-to-GR	017-0063-00
BNC, Male-to-GR	017-0064-00

TABLE 2-1 (cont)

Type	Tektronix Part Number
BNC, Male-to-N Female	103-0058-00
BNC, Female-to-UHF Male	103-0015-00
BNC, Male-to-UHF Female	103-0032-00
BNC, Male-to-Dual Binding Post	103-0035-00
BNC, Female-to-N Male	103-0045-00
BNC, Female-to-Dual Banana Jack	103-0090-00
BNC, Female-to-Clip Leads	013-0076-00
BNC, Male-to-Male	103-0029-00
Adapter, 50/125 Ω	017-0090-00
Adapter, 50/75 Ω	017-0091-00
Adapter, 50/93 Ω	017-0092-00
Terminator, 75 Ω BNC	011-0102-00

1502 Locating a Discontinuity in a Cable

The DISTANCE dial and the FEET/DIV (METRES/DIV) control make it possible to evaluate cables as long as 2000 feet (500 metres). The entire length can be displayed directly on the crt if desired. If a chart recorder is used, only that portion of the trace seen on the crt will be recorded on the graph.

To check cables using only the crt display, the FEET/DIV (METRES/DIV) control and the X1/X.1 control must be set so that the crt display window is longer than the cable. For example, if the cable is 150 feet (46 m) long, set the FEET/DIV (METRES/DIV) to 200 (50) and the multiplier at X.1.

NOTE

Use the X.1 multiplier whenever possible to lessen the effects of jitter.

This setting of the FEET/DIV (METRES/DIV) control assures that the reflected signal will appear in the display window. Measure the distance between the incident pulse rise and the reflected pulse rise.

NOTE

The distance from the sampling bridge to the CABLE connector (2.5 inches or 6.35 cm) should be taken into account when measuring cables less than 2 feet (50 cm) in length.

To more accurately locate the discontinuity, set the FEET/DIV (METRES/DIV) control to a lower setting. (The reflected pulse does not need to be in the display window.) Adjust ZERO REF SET button so that the incident pulse rise is set at a convenient vertical reference graticule line. The ZERO REF SET may have to be readjusted when changing the FEET/DIV (METRES/DIV) control.

NOTE

Always set the incident and reflected pulse to the 10% points of their amplitude (see Fig. 2-3).

Now turn the DISTANCE dial clockwise until the reflected pulse is located on the reference graticule line. The reading on the DISTANCE dial times the multiplier gives the length from the CABLE connector to the end of the cable (or to the discontinuity).

NOTE

When checking cables longer than 1000 feet (250 metres), adjust the DISTANCE dial until the reflected pulse reaches the right-hand edge of the graticule, then add the graticule display distance to that on the DISTANCE dial for the total length. The reading of the DISTANCE dial, plus the number of divisions (from the reference line) across the graticule times the FEET/DIV (METRES/DIV) setting gives the total length of the cable. Remember that in the 200 FEET/DIV (50 METRES/DIV) setting the DISTANCE dial is inoperative.

The CABLE DIELECTRIC pushbuttons allow the 1502 to accurately locate discontinuities in cables of various relative propagation velocity constant (V_p). The SOLID POLY button is calibrated to check solid polyethylene dielectrics which has a V_p of 0.66. The SOLID PTFE button is calibrated to check solid polytetrafluoroethylene (Teflon) which is a V_p of 0.70. The OTHER button is variable from 0.55 to 1.00 and is controlled by the screwdriver adjustment control VAR. When this screwdriver control is turned on to the fully clockwise position it is calibrated for air dielectrics which have a V_p of 1.00. If all three of the CABLE DIELECTRIC buttons are released, the 1502 goes into a default condition which leaves the instrument calibrated for air dielectrics ($V_p = 1.00$).

Evaluating a Discontinuity

The mρ/DIV control determines the vertical deflection that can be seen on the crt, or recorded on a graph if a chart recorder is used. The control is calibrated to measure the ratio of the reflected signal amplitude to the incident signal amplitude in rho (ρ) which is called the voltage reflection coefficient (rho is defined in Section 3 of this manual). For small values of ρ, an approximate value of deviation from

1502 Z_o in ohms per division, can be used for on-line evaluation of cables. Table 2-2 lists the approximate ohms per division for the various vertical deflection factors. See Fig. 3-1 for more complete information.

TABLE 2-2

R_L approximations for vertical deflection factors where $Z_o = 50\ \Omega$

mρ/DIV	$\Delta\ \Omega$/DIV
100	10
50	5
20	2
10	1
5	0.5

Fig. 2-4 shows the two parts of a TDR display appropriately labeled to identify the incident and reflected voltage signals. When ρ=0, the transmission line is terminated by a resistance equal to its characteristics impedance (Z_o) which is 50 Ω. When ρ equals +1, the

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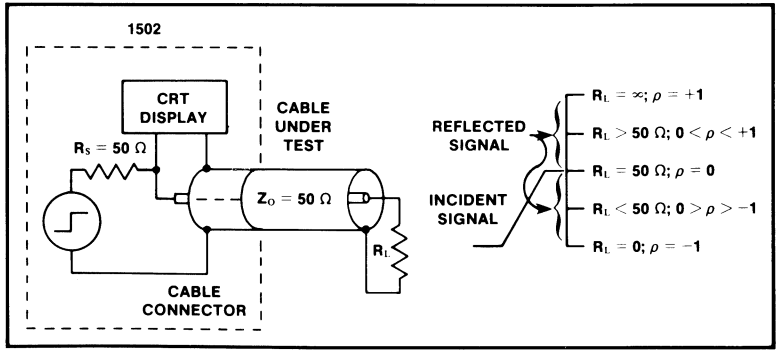

Fig. 2-4. TDR Display of R_L vs Z_o.

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transmission line load is an open circuit. When ρ equals −1, the transmission line load is a short. If the line is terminated by $R_L > 50\ \Omega$, ρ is positive and if the line is terminated by $R_L < 50\ \Omega$, ρ is negative.

Cables with a characteristic impedance other than 50 Ω can be evaluated by adjusting the GAIN control (screwdriver adjust) to correct the reflected pulse for +1 ρ at the open end of the cable. When the GAIN is changed, the incident pulse will no longer be 1 ρ.

To set the GAIN for an impedance other than 50 Ω, either connect an impedance matching adapter (50/75 Ω, 50/93 Ω, 50/125 Ω, etc.) to the CABLE connector and connect a short length of cable (with impedance the same as the adapter, i.e., 75 Ω, 93 Ω, 125 Ω, etc.) to the adapter or connect the cable to be tested directly to the CABLE connector. With the mρ/DIV set at 500, position the trace on the graticule so that the display of the cable is set on the horizontal center line and the open end of the cable appears in the display. Now adjust the GAIN control so that the open end display (reflected pulse) is set 2 divisions above the cable display (horizontal center line). This sets the reflected pulse to +1 ρ from the characteristic impedance.

The NOISE FILTER button can be used to reduce the noise displayed on the crt. The reduction in noise is accomplished by changing the time constant of the R-C filter and is accompanied by a slowing of the sweep rate.

1502 ACCESSORIES

Plug-ins

The 1502 plug-in compartment will accept either the X-Y OUTPUT MODULE (provided as a standard accessory) or the Tektronix Y-T Chart Recorder (Part Number 016-0506-00).

Using an X-Y Recorder

An X-Y recorder can be used with the 1502 by connecting it to the X-Y OUTPUT MODULE. Connect the X, Y, and PEN LIFT inputs of the recorder to the corresponding jacks of the X-Y OUTPUT MODULE. See the manual provided with the X-Y recorder for information on its use. Complete information on the X-Y OUTPUT MODULE is contained in the 1502 Instruction Manual.

Using a Tektronix Y-T Chart Recorder

The Tektronix Y-T Chart Recorder can be installed in the 1502 plug-in receptacle in place of the X-Y OUTPUT MODULE. The LOCK knob secures the chart recorder in the 1502. The recorder receives operating power and signal information from the 1502 and, using a hot stylus, records the signal on heat-sensitive paper.

When the RECORD/CAMERA switch is lifted toward RECORD, power is applied to the recorder stylus. The position of the stylus can be moved by adjusting the STYLUS POSITION screw while the switch is in the up position. This allows the stylus to be positioned to the same level as the trace on the crt before the recording is started.

When the RECORD switch is released, the chart recording starts; the chart record circuitry automatically shuts off when the recording is completed. Extra graph paper is run to allow removal of the recording.

In evaluating a graph, the distance between two dark horizontal lines corresponds to one vertical division of the crt display with respect to the mρ/DIV setting; the distance between two dark vertical lines corresponds to one horizontal division of the crt display with respect to the FEET/DIV (METRES/DIV) setting.

The chart recorder can make up to 20 graphs on one complete charge of the batteries and the 1502 will still operate for a minimum of 5 hours. After 20 graphs are made, the time that the 1502 can be operated without recharging the batteries will be reduced by approximately three minutes per recording.

Installing Chart Recorder Paper

About 60 graphs can be made with one roll of chart recorder paper. A new roll of chart paper is installed in the following manner:

1. Turn LOCK knob ccw and pull chart recorder from 1502.

2. Pull forward on base of bezel and lift upward.

3. Remove empty spool from recorder by pulling upward.

4. Place new roll of graph paper in top of recorder and push into place between the spring-loaded paper holders. Be sure the grid of the paper faces up. (See Fig. 2-5).

5. Pull the paper over the rollers and down the front of the recorder. Align the graph paper such that one of the dark lines is lined up with the red line on the plate behind the chart paper (this sets the graph paper so that a recording will start at one of the dark lines which corresponds to the edge of the crt graticule).

6. When the paper is properly aligned, lower the bezel until it latches into place, then place the chart recorder back into the 1502 turning the LOCK knob clockwise to lock.

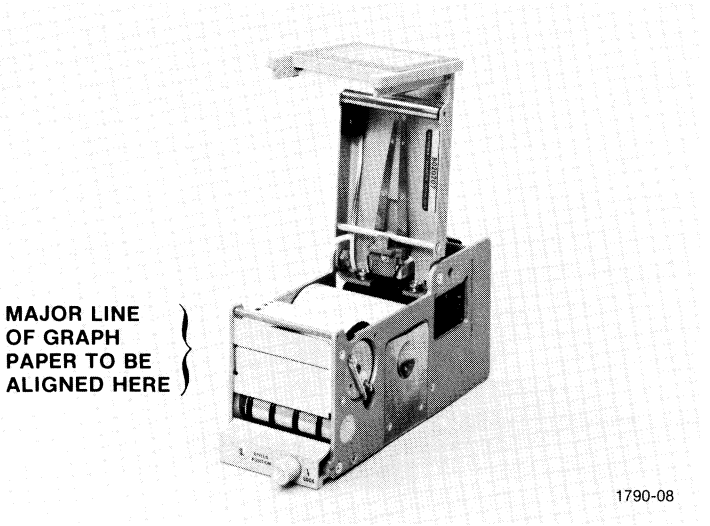

Fig. 2-5. Y-T Chart Recorder.

Mesh Filter for the crt

A mesh filter is provided with the 1502 which makes viewing of the crt easier when the unit is being used in the sunlight. This filter is placed over the crt by sliding it onto the slots of the crt bezel.

Viewing Hood

Another accessory provided with the 1502 for light shading is a viewing hood. This unit can be installed over the crt by sliding it down over the crt bezel sides. The mesh filter must be removed before the viewing hood will connect to the crt bezel.

Using a Camera with the 1502

If a Camera Adapter (Part Number 016-0327-00) is attached to the crt bezel of the 1502, a C-30A/31 camera can be used to take photographs of the crt display. To obtain graticule illumination for photographing, the RECORD/CAMERA switch has to be pushed down and held while the photograph is being taken. After the trace is completed, the entire crt is flooded to provide a light background to allow the dark graticule to appear in the photograph.

Nominal C-30A/31 camera settings are:

f/stop	5.6-11
time	1 s
magnification	1.2
focus	as necessary

Battery Care

To charge the batteries, connect the 1502 to a suitable ac power source. The battery pack will be fully charged in 16 hours. The batteries will not overcharge if left on longer than 16 hours so the 1502 can remain connected to an ac source without damaging the batteries.

Reverse charging a battery can damage it. Reverse charging can occur if an individual cell becomes discharged before the others. Such a case can develop due to cell aging, partial charging, or if a cell is replaced. If a cell becomes completely discharged, it is possible for it to become reverse charged by the current from the stronger cells. The battery charger is designed, using SCR protection circuits, to prevent accidental reverse charging. The SCR protection circuits automatically shut off the instrument whenever battery voltage falls below about 10 V.

To avoid reverse charging, the full 16 hour charge should be completed in preference to a partial charge cycle whenever possible (approximately 30 minutes of operating time can be expected from a 1 hour partial charge). In addition, approximately once a month or every 15 charge-discharge cycles (whichever occurs first), the batteries should be charged for approximately 24 hours.

The battery pack can be charged at any temperature between 0° C and +40° C and discharged (operated) at any temperature between −20° C and +40° C, but for maximum charge capacity, the cells should be charged at +20° C to +25° C. For more information refer to the Specification section of the Instruction Manual.

The power pack can be stored at any temperature between −40° C and +50° C with the battery cells either fully or partially charged. The self-discharge rate of the cells increases with increased temperature. A fully charged battery will lose about 50% of its charge in 3 to 4 months if stored at +20° C to +25° C. Therefore the battery pack should be completely recharged before using if it has been stored without power supplied to its charging circuit for more than a month.

The 1502 has been made with a ruggedized case that is suitable to provide protection when stored in exposed areas. When the instrument is not being used, the accessories, including the Operators Manual, should be packed in the instrument cover and the cover latched tightly on the front of the instrument.

INSTRUMENT STORAGE

The 1502 can be stored in temperatures between −62° C and +85° C, but if the temperature is below −40° C or exceeds +55° C, the batteries must be removed and stored in a location where the temperature is between −40° C and +55° C.

SECTION 3
MEASUREMENT CONCEPTS

The measurement of the reflected signal amplitude can be used to determine the impedance of a discontinuity. Fig. 3-1 shows the relationship between the amplitude of the reflected step pulse and the impedance of the discontinuity. Note that no reflection is obtained from a cable that has no discontinuities or is terminated with its characteristics impedance (for example, a 50 Ω cable terminated with 50 Ω). If a cable has an open, i.e., a break (∞ resistance), the reflected step pulse amplitude is +1 ρ; if a cable has a short (0 Ω), the reflected step pulse amplitude is −1 ρ. See Fig. 3-1 for a more complete chart showing reflected pulse amplitude-to-impedance conversion.

The source impedance of the 1502 is 50 Ω. If the characteristic impedance of the cable to be tested is other than 50 Ω, the GAIN control (screwdriver adjust) will have to be adjusted in order to maintain a reflected pulse amplitude of +1 ρ at the open end of the cable.

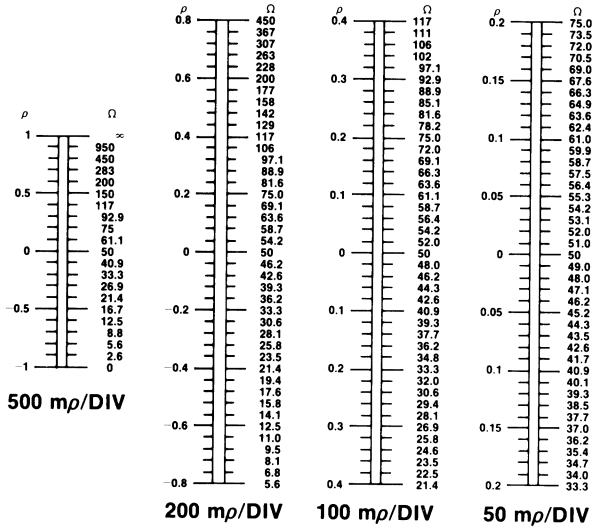

Fig. 3-1. R_L to Z_o Relationship where $Z_o = 50\ \Omega$.

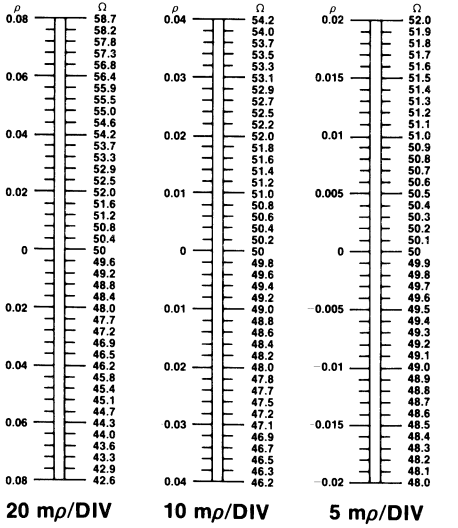

Fig. 3-1. (continued).

Rho is dependent on the characteristic impedance, Z_o, of the cable under test and the load (or the impedance of the discontinuity), R_L, on the cable. Therefore ρ can be defined as:

$$\rho = \frac{R_L - Z_o}{R_L + Z_o}$$

This relationship was used to develop the chart in Fig. 3-1.

Additional information can be found in the Time Domain Reflectometry application note which is enclosed with the 1502 Instruction Manual.