Entergy	NUCLEAR MANAGEMENT MANUAL	NON-QUALITY RELATED	EN-MA-138	REV. 0
		REFERENCE USE	PAGE 1 OF 27	

VLF Tan Delta And Withstand Testing Of Electrical Power Cables

Procedure Contains NMM eB REFLIB Forms: YES ☐ NO ☒

Effective Date	Procedure Owner: Title: Site:		Governance Owner: Title: Site:	
8/1/2011		Bret Baker Maintenance Mgr. PLP		Samuel Stewart Fleet Maintenance Mgr. HQN

Exception Date*	Site	Site Procedure Champion	Title
	ANO	Al Dodds	Manager, Maintenance
N/A	BRP		
	GGNS	Jeff Houston	Manager, Maintenance
	IPEC	John Kirkpatrick	Assistant Plant Manager
N/A	JAF	Michael Reno	Manager, Maintenance
	PLP	Brett Baker	Manager, Maintenance
	PNPS	James Taormina	Manager, Maintenance
	RBS	Clarence Bush	Manager, Maintenance
	VY	Mike Tessier	Manager, Maintenance
	W3	Brian Lindsey	Manager, Maintenance
N/A	NP		
	HQN	Samuel Stewart	Manager, Fleet Maintenance

Site and NMM Procedures Canceled or Superseded By This Revision

This procedure revision supersedes Palisades site Work Instruction WI-MSE-E-17

Process Applicability Exclusion: All Sites: ☐

Specific Sites: ANO ☒ BRP ☐ GGNS ☐ IPEC ☐ JAF ☐ PLP ☒ PNPS ☐ RBS ☐ VY ☒ W3 ☐ NP ☐

Change Statement

New procedure developed for the purposes of providing instructions for performing VLF Tan Delta and Withstand testing for electrical power cables.

JAF has determined that per EN-DC-346 they have no cables requiring the use of Tan Delta/Withstand testing. Therefore they will not be implementing this procedure at their site.

*Requires justification for the exception

TABLE OF CONTENTS

1.0 PURPOSE

[1] The purpose of this procedure is to provide instructions for performing Tan Delta diagnostic testing and Withstand testing of shielded medium voltage cables using a Very Low Frequency (VLF) source. This document provides information and guidance for using the VLF (Model HVA30/60) and Tan Delta (TD30/60) diagnostic testing instrumentation which will be referred to as HVA and TD.

[2] Passing a Withstand test after a successful Tan Delta test indicates that there is no significant distributed or local degradation of cable insulation. Tan Delta testing evaluates the cable for water-related degradation and Withstand testing determines whether severe localized degradation exists.

2.0 REFERENCES

[1] HV Diagnostics Portable Tan Delta Measurement System "Operating Manual TD 30"

[2] HV Diagnostics "Operating Manual HVA30"

[3] IEEE-400.2 - 2004, "IEEE Guide For Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF), " IEEE Power Engineering Society

[4] EPRI Report 1020805. "Plant Support Engineering: Aging Management Program Guidance For Medium-Voltage Cable Systems For Nuclear Power Plants"

[5] Entergy Procedure EN-DC-346, "Cable Reliability Program"

3.0 DEFINITIONS

[1] Acceptance Test – A field test made after cable system installation, including terminations and joints, but before the cable system is placed in normal service. The test is intended to detect installation damage and to show any gross defects or errors in installation of other system components.

[2] Diagnostic Test - A field test made during the operating life of a cable system. It is intended to determine and locate degradation that may cause cable and accessory failure.

[3] Device Under Test (DUT) - The electrical apparatus such as the cable being tested.

[4] Extruded Cables - Cables such as Butyl Rubber, EPR, XLPE, TR-XLPE, PE insulated cables.

[5] Installation Test - A field test conducted after cable installation but before jointing (splicing) or terminating. The test is intended to detect shipping, storage, or installation damage

[6] Maintenance Test - A field test made during the operating life of a cable system. It is intended to detect deterioration of the system and to check the serviceability so that suitable maintenance procedures can be initiated.

[7] Measuring and Test Equipment (M&TE) – All of the measuring instruments, measurements standards, reference materials and auxiliary apparatus including computers and media that are necessary to perform a measurement used to assure that important parts of nuclear generating stations are in conformance with prescribed technical requirements and that data provided by testing, inspection, or maintenance are valid.

[8] Tan Delta (Dissipation Factor) Test - Low frequency test performed on shielded Medium Voltage cables to assess the global condition of the insulation. The test determines the amount of dielectric leakage through the insulation to ground which indicates the presence of water trees

[9] Time Domain Reflectometry (TDR) - A TDR test set is used to help identify the presence of conductor splices or shield degradation.

[10] VLF – Very Low Frequency is an alternating AC voltage waveform, as found in AC power distribution systems, that has a nominal frequency of 0.1 Hz (or one cycle every 10 seconds). The waveform recommended is that of smooth, load independent Sine wave as found in normal AC power systems and the frequency should be optimized and kept as close to 0.1 Hz as possible.

[11] Withstand Test – High potential test to determine whether cable is acceptable for energizing and placing back into service. This test applies a low frequency high voltage AC waveform to the cable under test. The instrument measures the capacitance, insulation resistance (Megohm), charging current, test duration, and dielectric withstand capability of the cable

4.0 RESPONSIBILITIES

4.1 The **Maintenance Manager** is responsible for:

[1] Ensuring Maintenance compliance with this procedure.

4.2 The **Maintenance Supervisor** is responsible for:

[1] Ensuring that a pre-job brief is conducted.

[2] Ensuring equipment is removed from service prior to testing.

[3] Ensuring that procedural requirements have been met prior to work package closeout.

[4] Verifying that any applicable qualifications are up to date.

4.3 **Maintenance Craft Personnel** are responsible for:

[1] Implementing this procedure.

[2] Understand and adhere to procedural requirements.

[3] Notifying Responsible Engineer of test results.

4.4 The **Planning Supervisor** is responsible for:

[1] Ensuring compliance with model work order planning in accordance with EN-WM-105.

4.5 The **Planner** is responsible for:

[1] Ensuring the work package includes this procedure.

[2] Ensuring compliance with EN-WM-105 including tagging, rigging, and radiological requirements are identified and included in the job plan.

4.6 The **Responsible Engineer** or **Designee** is responsible for:

[1] Assisting Maintenance Craft Personnel or Planning as required.

[2] Identifying test voltages to be used for cable(s) to be tested

[3] Reviewing and approving completed test data and/or resolving testing issues.

5.0 DETAILS

5.1 PRECAUTIONS AND LIMITATIONS

[1] Tan Delta testing is only applicable for shielded, medium voltage cables. Unshielded cables have an inconsistent, unreliable ground plane. VLF AC Hi-Potential Withstand testing may be used for shielded or unshielded cables.

[2] Tan Delta and VLF Withstand testing require disconnecting cables from transformer or motor windings. Tan Delta testing requires disconnection of parallel conductors as necessary to test only one conductor at a time. Deviations from test setups described in this procedure may be made when approved by Engineering and described in the authorizing work order.

[3] The HVA Tan Delta tester may <u>not</u> correctly test cables that are greater than 5000 feet long.

5.2 GENERAL

[1] This procedure is not a stand alone document and should be used with other approved instructions to facilitate removal from service of cable(s) to be tested.

[2] This procedure does not provide instruction on repair, refurbishment, or replacement of cables.

[3] As determined by Engineering and directed by work order, ensure cables are disconnected from buswork. If cables are left connected to buswork on either end and poor test results are obtained, then cables should be disconnected and retested.

[4] VLF Tan Delta testing should be done in three steps, as shown in the table below. Engineering is to determine the appropriate test voltages, using these guidelines. Testing is done from each conductor to ground. Test voltages are calculated from system operating voltage to ground, not phase to phase voltage and not cable rated voltage. Operating voltage to ground (Vo) is [$V_{phase\text{-}to\text{-}phase}$ / SQRT(3)] for wye-connected three phase systems. Operating voltage is considered to be equal to $V_{phase\text{-}to\text{-}phase}$ for delta connected three phase systems.

Examples: 1) for a 4160 VAC grounded wye system, Vo = 4160 / SQRT(3) = 2400; 2) for a 2400 VAC ungrounded delta system, Vo = 2400.

(a) Engineering may choose different test voltages than what would be determined above for special circumstances, such as when testing known degraded cable or when no spares are available, etc.

(b) VLF Tan Delta testing should be done in three steps, as shown below (Engineering to determine appropriate voltages):

	Step 1	**Step 2**	**Step 3**
Time	3-min	3-min	3-min
VAC	0.5 V_O	V_O	1.5 V_O
Record Appropriate Test Voltages:			

(c) VLF AC Hi-Potential withstand testing is to be done at cable rated voltage for 30 minutes for Maintenance Tests. This is based on IEEE-400.2, except the maintenance tests are to be performed with a lower voltage at a longer time as discussed in EPRI-1020805 (page 5-4), to help avoid causing unnecessary cable failures during testing. Unless otherwise specified by Engineering, the following table shall be used to determine the appropriate withstand test voltage (Engineering to determine appropriate voltages).

Cable Rating Phase to Phase	**Installation Test – phase to ground (kV)**	**Acceptance Test – phase to ground (kV)**	**Maintenance Test – phase to ground (kV)**
rms voltage (kV)	**rms or (peak voltage)**	**rms or (peak voltage)**	**rms or (peak voltage)**
5	9 (13)	10 (14)	5 (7)
8	11 (16)	13 (18)	8 (11)
15	18 (25)	20 (28)	15 (21)
25	27 (38)	31 (44)	25 (35)
35	39 (55)	44 (62)	35 (49)

Test Type (circle one)	Maintenance Test	Installation Test	Acceptance Test
Time	30-min	30-min	30-min
Record Appropriate Test Voltage per Engineering:			

(d) For VLF AC Hi Potential Withstand testing, multiple parallel conductors within each phase may be bolted together for testing to reduce overall testing time. If test results are questionable with parallel conductors, it may be necessary to separate the conductors and test again.

(e) Test setups using HVA tester are to be 0.1 Hz, sine wave, trip out on arc, and no reporting.

[5] Discrepancies and corrective actions taken as a result of conditions identified during the performance of this procedure shall be recorded on the PCRS.

[6] Establish and release tagout clearances in accordance with EN-OP-102.

[7] Obtain the following equipment to be used for testing:

(a) Tan Delta Tester, TD 30 or TD 60.

(b) VLF AC High Potential Tester, HVA 30 or HVA 60

(c) Corona balls (Yo-Yos) for cable ends (Tan Delta kit typically contains two or three).

(d) Time Domain Reflectometry (TDR) Tester.

5.3 TEST SETUP

[1] **ENSURE** cable to be tested is isolated (eg, breaker(s) opened and tagged).

[2] Use Live-Dead-Live check to **ENSURE** cable to be tested is deenergized.

[3] As necessary, **ENSURE** conductor to be tested is disconnected or isolated at both ends.

[4] IF end of cable to be tested is terminated with a separate connector (eg, elbow connector), THEN **ENSURE** connections are mated to a temporary termination per directions from connection manufacturer to prevent tracking and/or flash-over.

[5] **ENSURE** proper cable end treatments (eg, stress cones) are installed as designed.

[6] IF both ends of cables shield are accessible, THEN **CHECK** cable shield for end-to-end continuity (nominally zero ohms).

[7] IF shield continuity check is unsatisfactory, THEN **CONTACT** Assigned Supervisor.

[8] **ENSURE** shield(s) of cable to be tested is/are connected to ground.

NOTE: At the discretion of Engineering and as directed by applicable work order, Time Domain Reflectometry (TDR) testing in the following two steps may be omitted.

[9] **CHECK** cable conductors that will be Tan Delta tested with Time Domain Reflectometry (TDR) tester.

[10] **PREPARE** TDR report for work order and for cable program engineer.

[11] **ENSURE** cable to be tested has adequate clearance from any other grounded object(s):

(a) A rope or tape may be used to tie back cable(s).

(b) All mechanical support connections on cable to be tested should be back away from stress cone part of termination.

[12] **ENSURE** power "On/Off" key switch on HVA front panel is "OFF."

[13] **ENSURE** Main "On/Off" switch on HVA side panel is in "O" (OFF) position.

[14] **ENSURE** Red "Emergency Off" pushbutton is latched in by depressing pushbutton located on HVA front panel.

[15] **REMOVE** External Remote Control Interlock Plug from HVA side panel socket.

[16] **CONNECT** HVA unit Earth Connection point to ground.

[17] **CONNECT** TD unit Ground/Earth Cable to ground.

[18] **CONNECT** 110 - 230 VAC power supply (2 kW minimum) to HVA at Main Plug.

[19] **CONNECT** High Voltage Cable from Tan Delta to HVA High Voltage Output Connector.

[20] **PLACE** Tan Delta unit in tripod in open area away from objects and people (during testing the metal head will be energized with full test voltage).

[21] **REMOVE** top/dome of Tan Delta AND **ENSURE** two (2) fully-charged C cell batteries are in unit (positive terminal points toward cap).

[22] **ENSURE** battery cap is screwed down AND **PERFORM** the following:

(a) **TURN** Tan Delta power to "I" (ON) position.

(b) **ENSURE** LED lights located on side of Tan Delta unit all illuminate, THEN Blue LED continues to flash.

[23] Taking care to not cross-thread cap threads, **REPLACE** metal cap on TD unit.

[24] **ESTABLISH** communications between Tan Delta and laptop via Bluetooth:

(a) **OPEN** TD "Control Center" icon on laptop.

(b) In TD Control Center Main Screen, **SELECT** "Connect to TD System."

(c) **ENSURE** status changes to "Connected to HVA TD."

(d) **ENSURE** serial number connected to laptop matches serial number on TD nameplate.

(e) As necessary, **CONTACT** Assigned Supervisor for further instructions.

[25] **CLEAN** Tan Delta unit with quick-drying denatured alcohol or approved alternate.

5.4 CABLE TESTING

[1] **CLEAN** cable ends with denatured alcohol or approved equivalent, including cable end treatments, all the way up to where shield exits jacket.

NOTE: Corona balls (yo-yos) must be in open space with no insulation covers.

[2] As necessary, **PLACE** supplied corona balls/yo-yos on opposite end of conductors to be tested to help eliminate sharp edges and corona.

[3] As necessary, **PLACE** supplied corona balls/yo-yos on near end of conductors to be tested to help eliminate sharp edges and corona.

NOTE: The test cable installed in the step will reach full voltage during testing, but test cable insulation is not designed to insulate high voltage from ground. Cable clearance may be achieved by moving TD and tripod to obtain proper orientation and distance in air.

[4] **CONNECT** Tan Delta head to cable to be tested:

(a) **INSERT** one end jumper cable in top of Tan Delta unit cap head.

(b) **INSERT** other end of jumper cable into hole drilled into corona ball.

(c) **ENSURE** jumper cable has minimal slack and is free and clear of any objects other than free air around cable.

[5] **ENSURE** HVA is turned on as follows:

(a) **ENSURE** Main "On/Off" switch on HVA side panel is in "I" (ON) position.

(b) **ENSURE** Power “On/Off” key switch on HVA front panel is in “ON” position.

NOTE:	When reviewing previously existing HVA Auto Test sequences in the following step, it must not be assumed from the title of an existing test sequence that all parameters meet requirements for cable to be tested. All menus must be reviewed as necessary to ensure all parameters meet testing requirements. Auto Test sequence menus are found under "Reports and Setup" and "Exit Auto Test Sequence."

[6] **ENSURE** correct Auto Test sequence exists in HVA unit as follows:

(a) **LOCATE** existing test that meets all test parameter requirements specified in previous steps (eg, number of steps, voltages times, 0.1 Hz sine wave, trip out on arc, and no reporting).

OR

(b) **CREATE** OR **REVISE** test that meets specified requirements.

[7] Using "Control Wheel" on front of unit, **SELECT** "Start A New Test" option from main menu (see Figure 1) OR **USE** last test sequence when performing same test on multiple cables.

Figure 1

[8] **SELECT** "No" to "Store a report" (TD reporting software on laptop will do reporting when TD is used with HVA (see Figure 2).

Figure 2

[9] **CLICK** on "Auto Sequence" to select "Automatic Test Sequence" (see Figure 3).

Figure 3

[10] **SELECT** desired automatic test sequence (from those identified in Step 5.4[3]), THEN **PRESS** "Next" to continue (see Figure 4)

Figure 4

[11] **ENSURE** cable/conductor under test is identified in laptop control center.

[12] **SELECT** appropriate phase to be tested on upper right hand corner of laptop "Control Center" screen.

[13] **INSERT** "External Remote Control Interlock" plug on left side of HVA unit.

[14] **RELEASE** "Emergency Off" pushbutton on top of HVA unit by depressing and twisting pushbutton.

NOTE:	The next two steps should be completed with less than 10 seconds between steps for the high voltage to be applied. Both steps will have to be repeated if more than 10 seconds elapsed between steps.

WARNING

The next two steps will energize the Tan Delta unit to test voltage. Personnel shall be kept away from the unit to avoid potential electrical shock..

[15] WHEN appropriate test sequence has been selected, THEN **PRESS** "Start" (see Figure 5)

Figure 5

[16] **PRESS** Green I/O button on HVA front panel to activate high voltage.

(a) IF any interlocks have not been cleared, THEN "Release Emergency Off" text will be displayed on window and high voltage will not turn on.

(b) IF message appears, THEN **CHECK** "Emergency Off" button and "Side Emergency Off" Interlock" plug (see Figure 6).

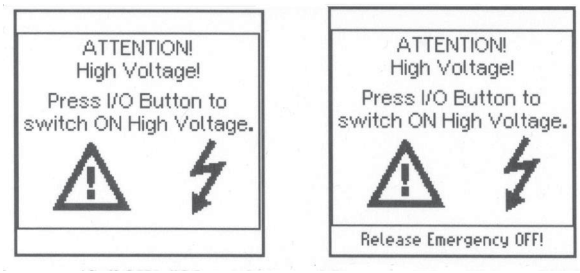


Figure 6

[17] **ENSURE** Graphic Display on HVA displays test waveform and test data.

[18] **ENSURE** laptop is capturing data (laptop will not show data until after one minute of test time).

[19] As desired at any time during or after test, **ENTER** comments or other desired information.

> ***CAUTION***
>
> During testing if at any time the Standard Deviation is greater than 0.04, the test must be stopped to prevent further damage to cable.

[20] **DEPRESS** to latch in Red Emergency Off pushbutton on HVA front panel.

[21] **REMOVE** External Remote Control Interlock plug from HVA side panel socket.

[22] **ENSURE** cable is discharged using suitable discharge or grounding stick.

[23] **EVALUTE** test result per Attachment 9.1.

(a) IF testing results are not "Good", THEN **PROCEED** to Step 5.4 [24].

(b) IF testing results are "Good", THEN **GO TO** Step 5.4 [25].

[24] **REQUEST** Responsible Engineer to determine appropriate action per Attachment 9.2.

[25] **DISCONNECT** test lead from corona ball of cable under test.

[26] For applicable type of test, **PERFORM** one of the following:

(a) For Tan Delta testing:

(1) IF additional conductor is to be Tan Delta tested, THEN **REPEAT** Steps 5.4[1] through 5.4[24].

(2) IF Tan Delta testing on all conductors is complete, THEN **PROCEED** to Step 5.4[27].

(b) For Withstand Testing:

(1) IF Additional conductor(s) is/are to be Withstand tested, THEN **PROCEED** to Step 5.4[28].

(2) IF Withstand testing of all conductors is complete, THEN **PROCEED** to Step 5.4[29].

[27] **DETERMINE** whether Withstand testing will be performed:

(a) IF Withstand testing will be performed, THEN **PROCEED** to Step 5.4[28].

(b) IF Withstand testing will not be performed, THEN **GO TO** Step 5.4[29].

[28] **REPEAT** Steps 5.4[1] though 5.4[26], using Withstand test voltage and time as one single step in the automatic sequence.

[29] **CLICK** on "Save Report" button to save test data.

[30] **SAVE** a copy of test report from laptop as follows:

(a) From TD Control Center software on laptop, **SELECT** "Print report."

(b) **SELECT** printer Microsoft XPS Document Writer (or equivalent).

(c) **SAVE** file to a flash drive or equivalent.

5.5 COMPLETION

[1] **ENSURE** Power "On/Off" key switch on HVA side panel is in "OFF" position.

[2] **ENSURE** Main "On/Off" switch on HVA side panel is in "O" (OFF) position.

[3] **DISCONNECT** power supply to HVA unit.

[4] **REMOVE** all connections from cable and HVA unit.

[5] **REMOVE** top/dome of Tan Delta AND **PERFORM** the following:

(a) **PLACE** Tan Delta power switch to "O" (OFF) position.

(b) **REMOVE** batteries.

[6] **INSERT** "External Remote Control Interlock" plug on left side of HVA unit.

[7] **RETURN** all equipment to storage as directed by Assigned Supervisor.

[8] **ENSURE** all temporary grounds are removed.

[9] **ENSURE** cables are reconnected per applicable work order steps.

[10] **ENSURE** a copy of test report for each test performed is printed out and attached to work order for records.

Performed By: _____ /

Repairperson Date

[11] **ENSURE** Electronic or Printed copy of test report for each test performed is forwarded to Responsible Engineer.

Performed By: _____ /

Repairperson Date

[12] **DOCUMENT** completion of work.

Performed By: _____ /

Repairperson Date

5.6 ACCEPTANCE CRITERIA

[1] All tested cable results are "Good" per Attachment 9.1.

[2] A Condition Report has been issued for any final result other than "Good."

6.0 INTERFACES

[1] EN-DC-310, Predictive Maintenance Program

[2] EN-MA-105, Control of Measuring and Test Equipment

[3] EN-MA-118, Foreign Material Exclusion

[4] EN-OP-102, Protective and Caution Tagging

[5] EN-WM-105, Planning

7.0 RECORDS

None

8.0 SITE SPECIFIC COMMITMENTS

None

9.0 ATTACHMENTS

[1] Attachment 9.1, "Testing Results Evaluation”
[2] Attachment 9.2, “Engineering Evaluation And Actions"
[3] Attachment 9.3, “Test Equipment Aid”

NOTES:

1. In the tables below, the term delta-Tan delta indicates the value of the difference in Tan delta results measured at $1.5V_o$ and $0.5V_o$. The difference in tan delta is normally positive (eg, higher Tan delta results at higher test voltages).
2. Negative differences should be treated as very significant and may indicate a problem with a test or an indication of the presence of a significant defect.
3. All Tan delta results are in terms of $x10^{-3}$, measured at a test frequency of 0.1 Hz.

1.0 **DOCUMENT** below which of the following Tan Delta Assessment Criteria Tables (1 through 5) are being used and basis for selection.

_____

_____

_____

2.0 **DOCUMENT** below results of review.

☐ Good

☐ Further Study Required - CR Number: _____

☐ Action Required - CR Number: _____

Table 1

Tan Delta Assessment Criteria for Butyl Rubber Insulation					
Condition	Tan Delta	----	Delta-Tan Delta	----	Percent Standard Deviation of Tan Delta Measurements at all Test Voltages
Good	< 12	and	< 3	and	< 0.02
Further study required	12 to 50	or	3 to 10	or	0.02 to 0.04
Action required	> 50	or	> 10	or	> 0.04

Table 2

Tan Delta Assessment Criteria for Black EPR Insulation					
Condition	Tan Delta	----	Delta-Tan Delta	----	Percent Standard Deviation of Tan Delta Measurements at all Test Voltages
Good	< 12	and	< 3	and	< 0.02
Further study required	12 to 50	or	3 to 10	or	0.02 to 0.04
Action required	> 50	or	> 10	or	> 0.04

Table 3

Tan Delta Assessment Criteria for Pink EPR or Gray UniBlend EPR Insulation					
Condition	Tan Delta	----	Delta-Tan Delta	----	Percent Standard Deviation of Tan Delta Measurements at all Test Voltages
Good	< 15	and	< 3	and	< 0.02
Further study required	15 to 30	or	3 to 8	or	0.02 to 0.04
Action required	>30	or	>8	or	>0.04

Table 4

Tan Delta Assessment Criteria for Brown EPR Insulation					
Condition	Tan delta	----	Delta-Tan Delta	----	Percent Standard Deviation of Tan Delta Measurements at all Test Voltages
Good	< 50	and	< 5	and	< 0.02
Further study required	50 to 60	or	5 to 15	or	0.02 to 0.04
Action required	> 60	or	> 15	or	> 0.04

Table 5

Tan Delta Assessment Criteria for XLPE Insulation					
Condition	Tan delta	----	Delta-Tan Delta	----	Percent Standard Deviation of Tan Delta Measurements at all Test Voltages
Good	< 1.2	and	< 0.6	and	< 0.02
Further study required	1.2 to 2.2	or	0.6 to 1.0	or	0.02 to 0.04
Action required	> 2.2	or	> 1.0	or	> 0.04

Table 6

VLF Withstand Test Assessment Criteria			
Condition	Cable Condition	----	Percent Standard Deviation of Tan delta Measurements at all Test Voltages
Good	No failure during withstand test	and	< 0.02
Further study required	No failure during withstand test	and	> 0.02
Action required	Failed during withstand test	----	----

1.0 Engineer shall **EVALUATE** test results AND **RECOMMEND** subsequent actions per the following:

Condition	Recommended Actions
Further study required	Cable passed marginally, indicating degradation of cable insulation, but not to the extent that a near-term failure is expected. Engineering evaluate test equipment and cable under test for cleanliness and appropriate positioning of test equipment. Compare to historical trends (if trend information exists). Attempt retest if test setup problems are possible cause.
Action Required: Poor Tan Delta test results, but no cable failure during Withstand Test	Cable passed marginally, indicating possible near-term failure if put back in service. Poor Tan delta test values likely indicate significant cable degradation of overall cable. Instability in Tan delta during withstand testing likely indicates that a significant degradation site exists and is in the process of going to failure. Engineering evaluate test equipment and cable under test for cleanliness and appropriate positioning of test equipment. Compare to historical trends (if trend information exists). Attempt retest if test setup problems are possible cause.
Action Required: Cable failure during Withstand Test	Cable failed test, and needs to be repaired or replaced.

2.0 Responsible Engineer **DOCUMENT** (✓) below recommended action.

☐ Testing to be Repeated

☐ Testing Not to be Repeated

☐ Withstand testing to be performed (if not already completed)

☐ Withstand testing Not to be performed (if not already completed)

Front Panel Description:

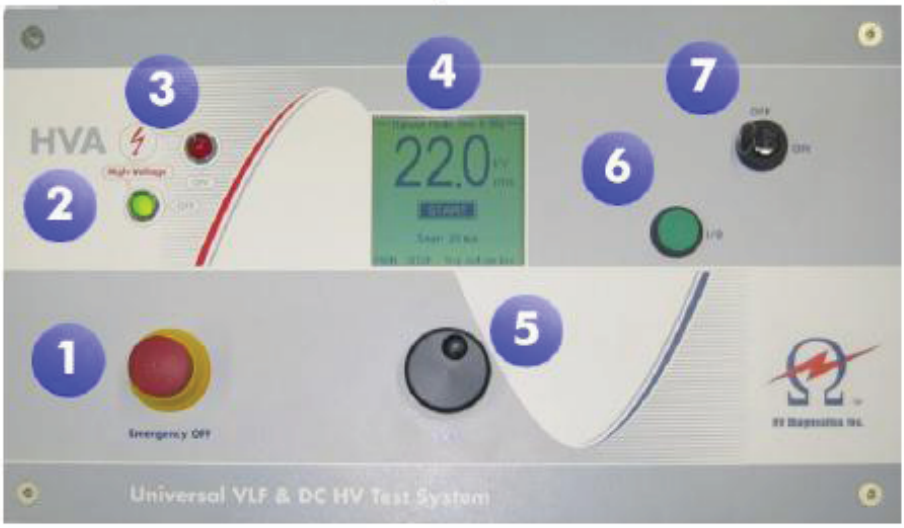


Figure 1:

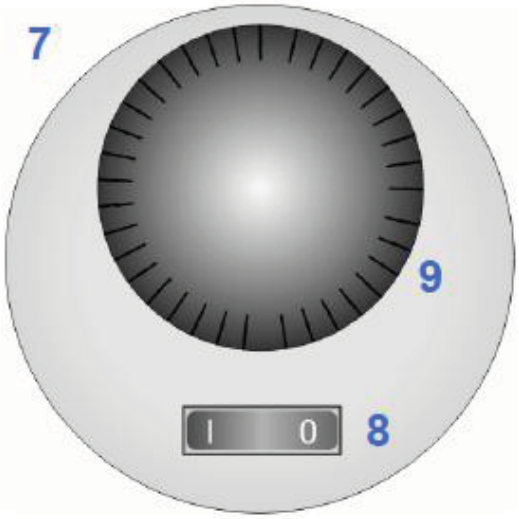
1	Emergency OFF	Emergency Off with Latch. To release latch, rotate the switch. When depressed, emergency off is activated. When released, emergency off is deactivated and HV may be activated.
2	LED Green	High Voltage is OFF when this light is activated
3	LED Red	High Voltage ON (DANGER) when this light is activated.
4	Graphic Display	128 x128 Backlight Display
5	Navigation Wheel / Knob	ENTER /SELECT – Press Wheel SCROLL UP or DOWN – Rotate left or Right
6	High Voltage ON/OFF	Pressing this button within 10 seconds after High Voltage is Released by test instrument (see display) will activate HV Output.
7	Power ON/OFF Key	Key Switch: This switch turns the unit on and off. Removal of the key in the OFF position will lockout the unit and HV will not be able to be activated. This is a useful feature to prevent unauthorized powering up of the instrument.

Side Panel Description:

1	Earth Connection	This is the first connection that should be made and the last to be removed. Connect to the ground of the DUT. Make sure earth cable is securely connected to this connector so that it cannot come loose inadvertently.
2	Main Plug	110V – 230V 50/60 Hz
3	External Remote Control Interlock Plug	PIN1 and PIN2 have to be short circuited to allow HV operation. This port can also be connected to a remote emergency off or other switch such as a gate, foot pedal or dead man switch. For all pin connections – please see Figure 3 below.
4	Main Switch ON/OFF	Integrated magnetic auto-resetable "fuse" 6A. The fuse will reset on turning switch "OFF" and then "ON" again.
5	High Voltage Output Connector	This connects to the HV Test Lead. To Connect HV test lead, screw the plug of the HV test lead into this socket until hand tight and firm. Attention: Never disconnect High Voltage Connector without first ensuring that the device under test has been discharged and grounded and the key switch is off.
6	Air Filter	Check air filter once a year. To check it, unclip outside plastic grill guard. If necessary replace it.

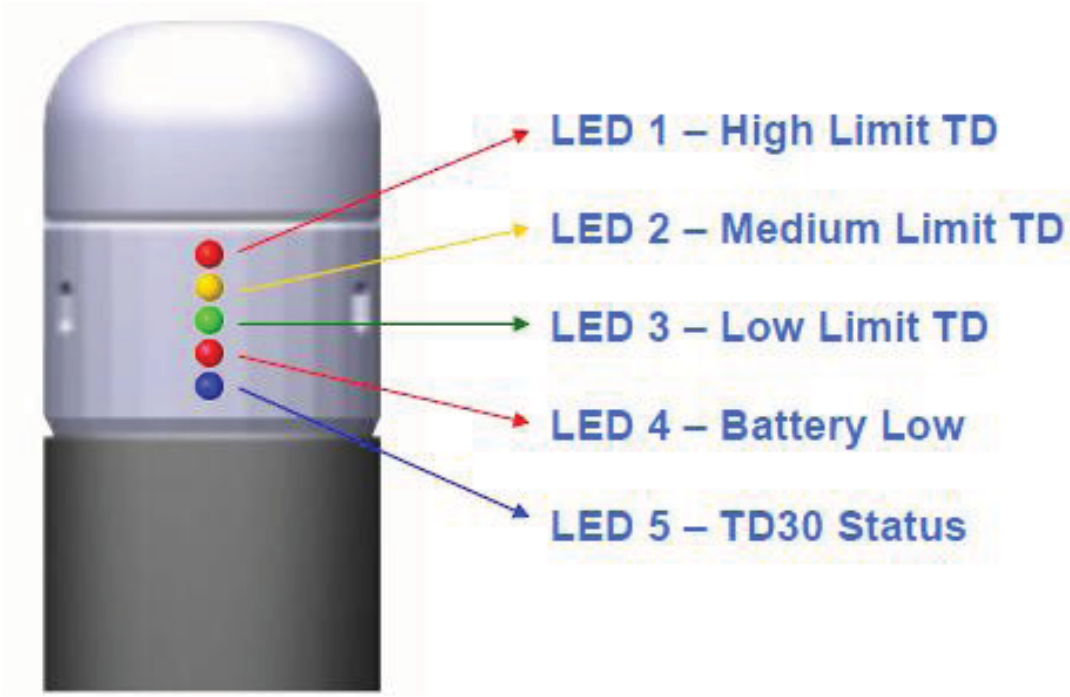
TD 30 Hardware Description:

1	TD System Housing	The TD System housing/enclosure. Note the TD30 will assume a potentially dangerous high potential / voltage during testing and measurement. Always keep the housing isolated and clear of any ground during testing. Depending on the application, the 3-Pod "Sputnik" Stand which is supplied can be used to ensure proper isolation.
2	High Voltage Cable	High Voltage connection cable that links the TD30 to the HVA generator.
3	High Voltage Plug HVA30	Plug directly into HVA30 HV output plug socket.
4	Ground/Earth Cable	Ground connection for load / station ground. Always connect this cable to a station ground. Do not use this cable to "ground" the Device Under Test without a suitable connection to a safe station / earth ground.
5	Aluminium Head	Aluminium Head covering the main ON/OFF switch and the battery housing. This head also incorporates an 8mm metric thread, which assists in providing a number of different connection options to the DUT. Unscrew head cap section to remove from the rest of the housing to turn ON/OFF the system or to replace the batteries. To re-install the head cap section, carefully screw on the cap, taking care not to cross thread the connection.
6	LED and Bluetooth® RF	5 LEDs showing operation status information. Do not cover this area.



The Head of the TD30 system with the Cap removed showing the Battery compartment and the ON / OFF switch.

7	TD system control	By removing the aluminium head cap the main switch and the battery housing can be accessed.
8	Main Switch	Switch for powering up or shutting down the TD system. It is advisable to turn off the system to conserve battery life if the system is not planned to be used for an extended period of time. The TD system incorporates an automatic power save sleep mode, which shuts down the system after no voltage (<1kV) has being sensed for 60 minutes or more. In this mode the main switch has to be set to 0 (off) for about 2 minutes and then on again to wake up the system manually, or you can reapply voltage with the HVA which will also wake up the unit.
9	Battery Compartment	Unscrew the cover of the battery compartment to replace or install batteries. 2 of C-Size 1.5V batteries are required. Insert the batteries with the + positive upwards (towards the operator) See Battery Cover for polarity marking if in doubt.



LED 1	Signal High TD (RED)	A flashing signal here indicates a TD level that is higher than the HIGH TD setting. If setup correctly, this will normally indicate a poor TD result. Flashing will occur simultaneously with the status LED signal. The TD HIGH limit can be set using the TD ControlCenter PC Software.
LED 2	Signal Medium TD (YELLOW)	A flashing signal here indicates a TD level that is lower than the HIGH limit and higher than the LOW limit. If setup correctly, this will normally indicate a mediocre (medium) condition. The limits of the TD value can be set using the TD ControlCenter PC Software.
LED 3	Signal Low TD (GREEN)	A flashing signal here indicates a TD level that is lower than the LOW limit. If setup correctly, this will normally indicate a good TD result. The limit of the TD value can be set using the TD ControlCenter PC Software.
LED 4	Signal Battery Low (RED)	Battery Low signal. Permanently ON if battery voltage drops below critical limit. In battery condition is OK then this light will not be ON.
LED 5	Signal Status (BLUE)	Flashing status signal showing active operation of the system.

Connection Diagram: