

	Standard	Technology
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ACCEPTANCE TESTING**

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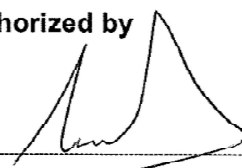
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1. Introduction

This procedure covers the testing of newly-installed Fibre Optic Cable Systems as well as any subsequent repair to existing installations.

2. Supporting clauses

2.1 Scope

This procedure covers the testing of Fibre Optic Cable Systems within Eskom. These systems may consist of Optical Ground Wire (OPGW), All Dielectric Self Supporting (ADSS), Externally Attached Cable, Duct Cabling or a combination of the above.

This procedure will form part of the fibre installation or repair Contract.

2.1.1 Purpose

The purpose of this document is to detail the requirements for the testing of Fibre Optic cables in Eskom.

2.1.2 Applicability

This document shall apply to Transmission and Distribution.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

- [1] ISO 9001 Quality Management Systems.
- [2] NRS 061-2 Specification for Overhead Ground Wire with Optical Fibre – Part 2: Installation Guidelines
- [3] NRS 078-2 ADSS Specification for All Dielectric Self-Supporting Fibre Optic Cable - Part 2 Installation Guideline
- [4] NRS 088-2 Duct or directly-buried underground optical-fibre cable : Part 2 : Installation Guidelines

2.2.2 Informative

- [5] Setting Splice Specifications for Single-Mode Fibre Cables – Corning White Paper WP7114
- [6] Single Fibre Fusion Splicing – Corning Application Note AN103
- [7] Testing Procedure for Network Deployment – EXFO Application Note 086
- [8] ORL Measurements in Field Applications – EXFO Application Note 140
- [9] QM-58: Eskom Standard: Supplier Contract Quality Requirements Specification

2.3 Definitions

2.3.1 General

None

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

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2.4 Abbreviations

Abbreviation	Description
10GigE	10 Gigabit Ethernet
ADSS	All dielectric self- supporting fibre optical cable
APC	Angle Polished Connector
CD	Chromatic Dispersion
FEC	Forward Error Correction
NCS	National Calibration Service
ODF	Optical distribution frame / Patch panel
OPGW	Overhead ground wire with optical fibre
OTDR	Optical time domain reflectometer
PC	Polished Connector
PMD	Polarisation Mode Dispersion
RL	Reflectance Loss
SDH	Synchronous Digital Hierarchy

2.5 Roles and responsibilities

Installation or repair work by the contractor is to be supervised by the Projects Department or the relevant Grid personnel. Acceptance testing is to be performed by Works Planning and Centralised Services Department or as otherwise specified by the Grid/Regions Secondary Plant Manager.

2.6 Process for monitoring

Not applicable.

2.7 Related/supporting documents

The document superseded by this document is TPC 41-5, Fibre Optic Cable System Acceptance Testing.

3. Requirements

3.1 Splice Acceptance Procedure

- a) All splice joints shall be done using a core alignment optical fusion splicer, splice losses shall comply with the following standard:

Fibre Splice Loss	
Single Mode Fibre	
Maximum Splice Loss	$\leq 0.15\text{dB}$
Mean Splice Loss	$\leq 0.05\text{dB}$
Multi Mode Fibre	
Maximum Splice Loss	$\leq 0.15\text{dB}$
Mean Splice Loss	$\leq 0.07\text{dB}$

Notes:

- 1) The Splice loss is the numerical average of an individual splice as measured in both directions with an Optical Time Domain Reflectometer (OTDR).
- 2) The mean splice loss is the sum of all individual splice losses on a particular fibre divided by the total number of splices on that fibre. Mean splice loss requirement is only relevant if the fibre optic link possesses five or more splices.
- b) Any joint which has a splice loss that is higher than the specified value shall be broken and redone a minimum of three times. If the optical loss in the joint cannot be contributed to micro bending and it is still not within specification after three splice attempts, a note to this effect shall be made in the test documentation. OTDR test results to this fact must be submitted as part of the documentation as proof.

3.2 Fibre Optic Testing Procedure

- a) The aim of these tests is to satisfy the Customer that the fibre optic installation is acceptable.
- b) After installation, or repair, the complete system shall be tested from end to end. The Customer shall be given the opportunity to carry out final acceptance testing in conjunction with the Contractor's staff. The Customer's presence shall not relieve the Contractor of his responsibility for the satisfactory performance of the equipment during site testing and thereafter through to the end of the warranty period.

Note: Before any optical tests are carried out, it must be ascertained that all of the fibre cores are matching 1 to 1. This should be verified using a Power Meter and Light Source end-to-end.

- c) For cable systems with one or more joints in the total length (excluding joints in Fibre Distribution units) the following tests is required: Optical Time Domain Reflectometer (OTDR) Testing, reporting the following results (i.e. attenuation coefficient, length and position and loss of splice joints, event Reflectance Loss (RL) and link Optical Return Loss (ORL)) should be made in accordance with IEC 60793-1-40.

Note: Set the OTDR length range at least as long as the fibre under test to avoid ghosting and echoing. These phenomena are particularly evident at short lengths (< 1km).

- d) Use the correct Group Refractive Index as provided by the optical fibre manufacturer and indicate this on the Splice summary Table in Appendix 1
- e) Set Helix Factor as stipulated by the supplier and indicate on the Splice summary Table
- f) Indicate the Backscatter coefficient for each wavelength as supplied by the cable manufacturer on the Splice summary Table
- g) Indicate Acquisition Time Settings on the Splice summary Table
 - 1) For final testing minimum of 45 seconds per wavelength shall be accepted.
- h) A 3m lead (patch-cord between OTDR and patch-panel input connection) shall be used to ensure a satisfactory launch situation for all measurements. A launch issue that cannot be cleared by cleaning shall be resolved with a "launch fibre" of at least 200m in length. The launch fibre finds faults in the area of the OTDR dead zone.
 - 1) The combined reflectance (ORL) resulting from the connection between the OTDR and the fibre under test shall be
 - >35dB (PC type connectors on Patch Panel)
 - >55dB (APC type connectors on Patch Panel)

Pay attention to cleaning of connectors before connecting fibre under test or test cord.

- i) For attenuation measurement, the test equipment wavelength tolerance shall be within $\pm 20\text{nm}$ of the central wavelength for 1310nm and 1550nm and $\pm 10\text{nm}$ for 1625nm.
- 1) line lengths up to 50 km attenuation measurements shall include all three test wavelengths.
 - 2) lines in excess of 50 km wavelength tests 1550nm and 1625nm is required.
 - 3) Under certain conditions and for low bit rate protection links, ESKOM could accept 1310 and 1550nm test results with prior consent for links up to 50km.
 - 4) Multimode Fibres require wavelength tests 850nm and 1300nm.
 - 5) Where fibre length is less than 200m only light source and Power Meter testing is required (no OTDR).
- j) The overall link (end-to-end) loss (attenuation) must be indicated in the summary sheet (Appendix 1).
- k) Event loss and attenuation measurements shall be based on bi-directional results when using the OTDR and in one direction using the light source and Power Meter.

Tests using a Power Meter and Light Source should be concluded before using an OTDR to ensure 1 to 1 matching of the fibre cores. Test results that include the above information must be submitted in a RAW un-edited format additionally test results must be submitted in abbreviated format as per Appendix A.

Note: The OTDR manufacturer's software must be used to analyse and calculate bi-directional splice loss.

- l) Bi-directional measurements with the same test conditions are required to eliminate the effects of backscatter coefficient differences. The loss calculation must be done on the OTDR manufacturer software, offline calculation using any other software is not allowed as it cannot be guaranteed.
- m) Ensure the Event Analysis; Event Thresholds and Event Notifier are set for maximum detection.

The following table for OTDR Maximum pulse widths must be adhered to:

Range	Maximum Pulse Width
< 2km	100ns
> 2km and < 20km	500ns
>20km and < 50km	1 000ns
> 50km	2 500ns
> 80km	10 000ns (10 μs)

The following information must be available as part of the actual test result;

- 1) Date and Time (Test was done)
- 2) Fibre Optic Cable Description,
- 3) Fibre Number
- 4) Test Direction (Site A and Site B)
- 5) Index of Refraction, Helix Factor and Rayleigh Backscatter Coefficient.

The following documentation must be submitted as part of Test Results

- 1) OTDR documentation stating (make, model, specifications)
 - a. Copy of the offline trace analysis software used for trace and bidirectional analysis.
 - b. Calibration certificate from the manufacturer, approved service centre or NLA accredited facility with a date not older than two years.

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- 2) Splice machine information / documentation
- a. Make, model, specifications
 - b. Service record / letter from manufacturer, certified service centre or NLA accredited facility, with a date not older than two years.
 - c. Record must include all service history on the equipment

Information must be summarised in table form as shown in the example in Appendix A of this Document.

- n) The end-to-end loss (ODF to ODF) must be measured from both ends using a light source and an optical power meter. Results for 1310nm, 1550nm and 1625nm windows are required for all fibre lengths.

Details of the instrumentation launch conditions and reference shall be provided in the documentation called for in clause 3.4. The results must be summarised in table form as shown in the example in Appendix B of this Document.

- o) Commissioning shall be done in close co-operation with, and to the full satisfaction of the relevant Eskom Department.
- p) Eskom reserves the right to have several/multiple technicians actively participate in the fibre section link tests with the object of them gaining intimate knowledge of the testing procedures.

3.3 End-to-end fibre optic link Characterisation

- a) Prior to the final acceptance of the fibre installation the link it shall be characterised for Polarisation Mode Dispersion (PMD) and Chromatic Dispersion (CD) as a requirement for assessing its overall acceptability and for the selection and configuration of the optical transmission equipment to be used.
- b) The end-to-end PMD performance shall be measured, from one end only, for each fibre, using an IEC acceptable test method. Measurements shall be done across the O (1260 to 1360 nm) & C (1550nm to 1565nm) bands and the measured r.m.s. value of the PMD shall be documented in the form shown in Appendix D.

Note: Recommended maximum acceptable PMD figures for equipment operating at various data rates are as follows:

Bit rate (Gbit/s)	Maximum Average PMD (ps)	PMD Coefficient (ps/√km)
2.5	40	< 2.0
10	10 (with no FEC)	< 0.5
40	2.5	< 0.125

Typically the maximum average PMD which can be tolerated is less or equal to one tenth the bit length at which the data channel is operating, assuming SDH transmission equipment.

The requirements for 10GigE are more stringent than for conventional 10Gbit/s SDH systems, the former would require an average PMD of 5ps for satisfactory operation.

- c) The end-to-end Chromatic Dispersion shall be measured on each fibre, from one end only. Minimum test wavelengths acceptable for calculating the dispersion slope on a fibre link shall be 7 wavelengths. Any test method using less than 6 test wavelengths is not accepted.

Results shall include the actual dispersion measurement results as well as the as calculated dispersion slope, including the zero dispersion wavelength.

Note: While, unlike PMD, CD can be readily compensated for by various means, terminal equipment can cope with a certain amount without the application of mitigation techniques. Typical equipment capabilities, related to bit rate, are as follows:

Bit Rate (Gbit/s)	Max. CD (ps)
2.5	18 817
10	1176
40	73.5

3.4 Documentation

- a) The supplier shall supply documentation as required in Schedule A of the contract - reference should also be made to Eskom Quality Requirements QM-58.
- b) All documentation called for shall be provided in hard covered ring files which comply with the following requirements:
 - 1) Supplied in English.
 - 2) A4 Paper Size.
 - 3) Of a construction that can open flat on any page.
 - 4) Any drawings and descriptions included shall conform to the A4 series (295mm x 220 mm). Larger Drawings shall be folded in a single panel along the 200 mm axis of the standard A4 size. Drawings which must be folded in two directions are not acceptable.
 - 5) Different sections of the documentation shall be separated by means of thumb-tag separators.
- c) The documentation shall include the following:
 - 1) Index.
 - 2) Details of fibre numbering and colour coding.
 - 3) Refractive index and backscatter coefficient of fibres incorporated in the cable(s)
 - 4) Manufacturer's specification sheets, including details of cable construction, both aerial and duct
 - 5) Fibre over-length (%) and helix factor in all cable types supplied
 - 6) System Diagram showing joint locations and distances between joints.
 - 7) Test Certificates for site tests of fibre before installation.
 - 8) Table of Joint Losses and Distances similar to the example in Appendix 1.
 - 9) Document specifying which towers have joints and down-leads etc which are insulated from the tower steelwork
 - 10) All test results shall be supplied in softcopy (CD or DVD in pdf and actual raw format as well as an electronic copy on Disc)
 - 11) Table of end-to-end attenuation using the light source/power meter technique similar to the example in Appendix B.
 - 12) Table of PMD delay measurements similar to the example in Appendix C.
 - 13) Table of CD delay measurements. similar to the example in Appendix D.
 - 14) List of manufacturer's code numbers of all hardware used in the installation (strain assemblies, suspension assemblies, down-lead clamps, earth-bonds etc)

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- 15) Complete set of drawings of all hardware used - strain assemblies, suspension assemblies, down-lead clamps, earth-bonds, joint enclosures and ODFs (when supplied as part of the main contract)
- d) Additional Documentation for ADSS Cables
- 1) Electro Magnetic Field Plots
- 2) Induced voltage and Leakage Current Graphs. (In high pollution Areas)
- 3) Dynamometer Recordings during Stringing

The contractor shall supply this to:

The contractor shall supply this to either:

- 1) Transmission

Telecommunications T&S Manager

Technology

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or

- 2) Distribution

The designated project manager within the Distribution Operating Unit.

4. Authorisation

This document has been seen and accepted by:

Name and surname	Designation
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Danie Du Plessis	Senior Manager Grids
Paul Grobler	Chief Engineer - Tx
Sikelela Mkhabela	Senior Manager - Dx
Prudence Madiba	Senior Manager - Gx
Joe Manyisa	Senior Manager - Eskom Telecommunications (Acting)
Nondumiso Zibi	Senior Manager - GIT

5. Revisions

Date	Rev	Compiler	Remarks
Aug 2016	2	V Naidu	Correction of 3.2h) 1. Greater than sign included.
Aug 2014	1	V Naidu	Replaces TP 41-5, new template, number number and new technical details.

6. Development team

The following people were involved in the development of this document:

- Bervonne Consulting (David C Smith)
- Antonio Pereira

7. Acknowledgements

Not applicable.

Annex A – Sample of Splice Loss and ORL Summary Table

Line : Bloukrans-Venus No 1

Fibre type: G652

Cable Type: AD-Lash

Refractive Index: 1.468

End 1: Bloukrans Substation

Helix Factor: 3%

End 2: Venus Substation

Wavelength: 1550nm (1310nm, 1625nm)

Type of connector – End 1: FCPC

Type of connector – End 2: SC

Backscatter Coefficient :

	Tested From		Total Length	Joint 1 Distance	Joint 3 Distance	Joint 9 Distance	Joint 11 Distance
	End 1		0	1926	5730	16686	20632
	End 2		21144	19218	15414	4458	506

Fibre No.	Tested From	Reflectance (dB)	Total Loss	Joint 1 Loss	Joint 3 Loss	Joint 9 Loss	Joint 11 Loss
1	End 1	- 41	5.11	0.11	0.00	0.00	0.00
1	End 2	- 37	5.324	0.06	0.12	0.00	0.00
1	Average		5.21	0.09	0.06	0.00	0.00
2	End 1	- 38	5.43	0.00	0.23*	0.00	0.00
2	End 2	- 42	5.21	0.00	-0.10*	0.00	0.00
2	Average		5.32	0.00	0.07	0.00	0.00
:	:		:	:	:	:	:
11	End 1	- 35	5.41	0.00	-0.07*	0.06	0.11
11	End 2	- 36	4.90	0.00	0.09*	0.00	0.11
11	Average		5.15	0.00	0.08	0.03	0.11
12	End 1	- 39	5.02	0.09	0.00	0.05	0.06
12	End 2	- 40	5.58	0.10	0.17*	0.00	0.00
12	Splice Loss		5.30	0.10	0.09	0.03	0.03

Mean Loss	Worst Splice Loss	ORL (dB)
0.04	0.09	End 1: End 2:
0.02	0.07	End 1: End 2:
:	:	
0.05	0.11	End 1: End 2:
0.06	0.10	End 1: End 2:

*This value indicates a gain at the joint due to a variation in the MFD of the two fibres.

*Total loss is the total line loss as read off during end to end testing and not only a sum of joint losses.

The above table is shortened for brevity

NB: It is not intended that the above table represents real values. It is illustrative only.

Type of OTDR equipment used : xyz Company. Type xxxx

Serial numbers : xxxxxxxx, xxxxxxxx

Date last calibrated: 20 June 1920

Name of Calibration agency: J&B Incorporated

Name of Operator: Joe Bloggs

Signature:-----

Date of measurement: 20 June 2011

Annex B – Sample of Power Source and Light Meter Summary Table

Line : Bloukrans-Venus No 1

Cable Type: AD-Lash

End 1: Bloukrans Substation

End 2: Venus Substation

Line Length: 21km

Wavelength: 1550nm (1310nm, 1625nm)

Reference: -7.3dB

Fibre no	Tested from	dB/km	Receive Level dBm	Loss dB
1	End 1	0.24	-12.4	5.1
1	End 2	0.25	-12.7	5.3
2	End 1	0.26	-12.5	5.4
2	End 2	0.25	-12.3	5.2
3	End 1	0.25	-12.8	5.3
etc				

(The above table is shortened for brevity.)

Type of equipment used : xyz Company. Type xxxx

Serial numbers : xxxxxxxx, xxxxxxxx

Date last calibrated: 20 June 1920

Name of Calibration agency: J&B Incorporated

Name of Operator: Joe Bloggs

Signature:-----

Date of measurement: 20 June 2011

Annex C – - Sample of PMD measurement summary table

Line : Bloukrans-Venus No 1

Cable Type: OPGW

Measurement End: Bloukrans Substation

Remote End: Venus Substation

Line Length: 21km

Fibre Number	r.m.s PMD delay (ps)	PMD Coefficient (ps/√km)
1		
2		
3		
4		
5		
etc		

(The above table is shortened for brevity.)

Type of equipment used : xyz Company. Type xxxx

Serial numbers : xxxxxxxx

Date last calibrated: 20 June 1920

Name of Calibration agency: J&B Incorporated

Name of Operator: Joe Bloggs

Signature:-----

Date of measurement: 20 June 2011

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Annex D – Sample of CD measurement summary table**Line :** Bloukrans-Venus No 1**Cable Type:** OPGW**Measurement End:** Bloukrans Substation**Remote End:** Venus Substation**Line Length:** 21km

Fibre Number	CD delay at 1310nm (ps)	Dispersion slope at 1310nm (ps/nm ² .km)	CD coefficient at 1310nm (ps/nm.km)
1			
2			
3			
5			
47			
48			

Fibre Number	CD delay at 1550nm (ps)	Dispersion slope at 1550nm (ps/nm ² .km)	CD coefficient at 1550nm (ps/nm.km)
1			
2			
3			
5			
.....			
47			
48			

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Fibre Number	CD delay at 1625nm (ps)	Dispersion slope at 1625nm (ps/nm ² .km)	CD coefficient at 1625nm (ps/nm.km)
1			
2			
3			
5			
.....			
47			
48			

(The above table is shortened for brevity.)

Type of equipment used : xyz Company. Type xxxx

Serial numbers : xxxxxxxx, xxxxxxxx

Date last calibrated: 20 June 1920

Name of Calibration agency: J&B Incorporated

Name of Operator: Joe Bloggs

Signature:-----

Date of measurement: 20 June 2011

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