

	TECHNICAL SPECIFICATION FOR OPTICAL GROUND WIRE AND FIBRE OPTICS FOR OVERHEAD TRANSMISSION LINE SYSTEMS	Doc.	TechSpec-OPGW and FO for OHTL Systems		
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REVISION CONTROL

Revision No.	Notes	Date
00	First Issue	24 February 2020
01	Revision 1: Removed reference to Lisa Termination System. Included reference for 19-inch Tray. Update specification for manholes and duct.	19 April 2021
02	Revision 2: Included detailed specifications for 19-inch termination tray. Updated images and reference diagrams for typical duct fibre cable construction, OPGW stringing arrangements and OPGW strain dead-end with pre-form wire wrap. Made general grammar and syntax corrections. Restructured the document. Removed some parts of the documents that were not required for the specifications.	13 September 2022

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PARTS: OPTICAL GROUND WIRE AND FIBRE OPTICS FOR OHL TRANSMISSION SYSTEMS

PART A: SPECIFICATION FOR THE SUPPLY OF OVERHEAD OPTICAL GROUND WIRE (OPGW), ALL DIELECTRIC SELF SUPPORTING (ADSS) AND METAL FREE OPTICAL FIBRE DUCT CABLE.

PART B: SPECIFICATION FOR INSTALLATION OF OVERHEAD OPTICAL GROUND WIRE (OPGW)

PART C: SPECIFICATION FOR INSTALLATION OF UNDERGROUND CABLE DUCT/TUBE FOR UNDERGROUND OPTICAL FIBRE CABLES

PART D: SPECIFICATION FOR THE INSTALLATION OF UNDERGROUND OPTICAL FIBRE DUCT CABLE INTO UNDERGROUND CABLE DUCT/TUBE

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PART A: SPECIFICATION FOR THE SUPPLY OF OVERHEAD OPTICAL GROUND WIRE (OPGW), ALL DIELECTRIC SELF SUPPORTING (ADSS) AND METAL FREE OPTICAL FIBRE DUCT CABLE

1. Introduction

1.1 Purpose and Scope

- 1.1.1 This specification sets out the requirements for the manufacture, testing and delivery of single mode optical fibre cables for use on eThekweni Electricity's High Voltage (HV) Transmission Network in a totally exposed environment. This document specifies the physical characteristics of Overhead Optical Ground Wire (OPGW), All Dielectric Self Supporting (ADSS) Overhead Optical Fibre Cable, and Underground Optical Fibre Duct Cable. This document includes the requirements for the erection, installation, termination and testing of the cables and the fibre links.

2. Normative References

2.1 General

- 2.1.1 Optical fibre cables (both for overhead and underground installation) shall be designed, manufactured and tested in accordance with the relevant parts of the Standards listed in this section as well as all amendments issued from time to time except where varied by this specification.

2.2 Optical Fibres

ITU-T G.652.D	Characteristics of a Single-Mode Optical Fibre
SANS/ IEC 60793	Optical Fibres
SANS/ IEC 60793-1	Optical Fibres: Part 1: Generic Specification
SANS/ IEC 60793-1-(1-54)	Optical Fibres: Part 1: Measurement methods and test procedures.
SANS/ IEC 60793-2	Optical Fibres: Part 2: Product specifications – General.
SANS/ IEC 60793-2-50	Optical Fibres: Part 2: Section 50: Product specifications- Sectional specification for class B single-mode fibres.
SANS/ IEC 60793-2-60	Optical Fibres: Part 2: Section 60: Product specifications- Sectional specification for category C single-mode intra-connection fibres.

2.3 Optical Fibre Duct Cables

SANS/ IEC 60794-1-1	Optical fibre cables Part 1- Section 1: General Specification- General
SANS/ IEC 60794-1-2	Optical fibre cables Part 1- Section 2: Generic specification - Basic optical cable test procedures- General guidance
SANS/ IEC 60794-3	Optical fibre cables Part 3: Sectional specification - Outdoor cables
SANS/ IEC 60794-3-10	Optical fibre cables Part 3- Section 10: Outdoor cables - Family specification for duct, directly buried and lashed aerial optical telecommunication cables
SANS/ IEC 60794-3-11	Optical fibre cables Part 3- Section 11: Outdoor cables - Detailed specification for duct and directly buried single-mode optical fibre telecommunication cables

2.4 Optical Ground Wires

SANS/ IEC 60794-4	Optical fibre cables Part 4: Sectional specification — Aerial optical cables along electrical power lines
SANS/ IEC 60794-4-10	Optical fibre cables Part 4- Section 10: Aerial optical cables along electrical power lines - Family specification for OPGW (Optical Ground Wires)

2.5 Conductors

SANS/ IEC 61089	Round wire concentric lay overhead electrical stranded conductors
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2.6 Other

SANS 1882	Polymer concrete surface boxes, manhole and inspection covers, gully gratings and frames
SANS 558	Cast iron surface boxes and manhole and inspection covers and frames
SANS 1200L	Standardized specification for civil engineering construction
SANS 1294	Precast concrete manhole sections and components
SANS 819	Fibre-cement pipes, couplings and fittings for sewerage, drainage and low-pressure irrigation
SANS 50124	Gully tops and manhole tops for vehicular and pedestrian areas - Design requirements, type testing, marking, quality control
SANS 121	Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods
SANS 1274	Coatings applied by the powder-coating process
SANS 161-2	Plastics - Polypropylene (PP) moulding and extrusion materials Part 2: Preparation of test specimens and determination of properties
OHS ACT	Occupational Health and Safety Act 85 of 1993, as amended
IEC 60304	Standard colours for insulation for low-frequency cables and wires
CIGRE 746	Design, deployment and maintenance of optical cables associated to overhead HV transmission lines

3. Drawings

3.1 Requirements

- 3.1.1 There are no drawings issued with this part of the specification (**PART A**). The Contractor shall supply the datasheets and cross-sectional drawings of the cables offered.

4. Environment

4.1 Exposure

- 4.1.1 Cables will be exposed to conditions as specified in **Schedule A**.

5. Overhead Optical Ground Wire (OPGW) Design and Construction

5.1 General

- 5.1.1 The physical properties of the optical fibre, the structure of the cable, and the testing of the cable must be understood by the Contractor and conform to the Standards of this specification.
- 5.1.2 The conductor shall consist of multi-layer aluminium alloy conductor strands. The conductor shall not contain any steel strands.
- 5.1.3 The fibre tube which house the optical fibres shall be an inner layer aluminium tube or stainless-steel tube filled with thixotropic gel. It is preferred that each tube shall have a maximum of 24 fibres per tube, the tube being under 4.00 mm diameter.
- 5.1.4 The alternating layers of stranded elements in the OPGW helps to create a cable possessing torsional balance which will reduce the tendency to rotate during installation.
- 5.1.5 The physical properties shall be designed such that standard hardware accessories can be utilised.
- 5.1.6 It is preferred that the cables be part of or become part of the standard product range produced by the manufacturer.

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5.2 Optical Fibre Requirements

5.2.1 The optical fibres will be single mode fibres with the following characteristics:

- (1) Each fibre shall be a single mode fibre and the characteristics of each single mode optical fibre in the optical fibre cable will adhere to the ITU-T's recommendation G.652.D (IEC 60793-2 B1.1 SMF Type) as specified in **Schedule A**.
- (2) The secondary fibre coating is required to be a tight UV Acrylate coating and shall be easily removed by mechanical means for jointing purposes. Preference is likely to be given to fibres, which have a primary buffer coating of 250 ± 15 μm low modulus UV, cured Acrylate material. Thus, Contractors are encouraged to offer prices for totally UV cured Acrylate coated fibres where possible. Contractors may offer more than one primary, buffer coating material. In such cases Contractors should provide as much information as possible regarding the physical, mechanical, and transmission performance of such fibres, with particular regard to the relative susceptibility to hydrogen degradation compared with UV Acrylate coated fibre.
- (3) The colours of individual fibres and tubes as well as other cable components shall allow for the unique identification of individual fibres within the cable and shall be in accordance with to ANSI/TIA/EIA-598.
- (4) The fibres shall not be jointed within any un-installed cable length (e.g. factory joints).

5.3 Drawings

5.3.1 Contractors shall provide detailed drawings of the cross-section of the items offered.

6. ADSS Design and Construction

6.1 General

- 6.1.1 The optical fibre cable as specified shall have single mode optical fibres in accordance with ITU-T Recommendation G.652.D.
- 6.1.2 The outside diameter of the ADSS Short Span cable shall be between 14 mm and 14.99 mm.
- 6.1.3 The outside diameter of the ADSS Long Span cable shall be between 18 mm and 18.99 mm.
- 6.1.4 The offered cables shall be completely metal free (all dielectric) and shall comply with the product approval requirements of SANS/ IEC 60794 and SANS/IEC 60793.
- 6.1.5 It is preferred that the cables be part of or become part of the standard product range produced by the manufacturer.

6.2 Optical Fibre Requirements

6.2.1 The optical fibres will be single mode fibres with the following characteristics:

- (1) The fibre shall be single mode fibre and the characteristics of each single mode optical fibre in the optical fibre cable will adhere to the ITU-T's recommendation G.652.D as specified in **Schedule A**.
- (2) The secondary fibre coating is required to be a tight UV Acrylate coating and shall be easily removed by mechanical means for jointing purposes. Preference is likely to be given to fibres, which have a primary buffer coating of 250 ± 15 μm low modulus UV, cured Acrylate material. Thus, Contractors are encouraged to offer prices for totally UV cured Acrylate coated fibres where possible. Contractors may offer more than one primary, buffer coating material. In such cases, Contractors should provide as much information as possible regarding the physical, mechanical, and transmission performance of such fibres; with particular regard to the relative susceptibility to hydrogen degradation compared with UV Acrylate coated fibre.
- (3) The colours of individual fibres and tubes as well as other cable components shall allow for the unique identification of individual fibres within the cable and shall be in accordance with ANSI TIA-598-D Optical Fibre Colour Coding.
- (4) The fibres shall not be jointed within any un-installed cable length (e.g. factory joints).

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6.3 Drawings

6.3.1 Contractors shall provide detailed drawings of the cross-section of the items offered.

7. Optical Fibre Duct Cable Design and Construction

7.1 General

7.1.1 These cables may have up to 96 fibres, loose tubes and fillers as defined in Technical Schedules A and B for Heavy-Duty Optical Fibre Duct Cable (**Schedule A**: Purchaser's specific requirements, Schedule B: Particulars of Tender Offer). Loose tubes are manufactured from high strength, low shrinkage compound, and each tube (colour sequence shown in **Annexure F**) will contain a maximum of 12 optical fibres (colour sequence shown in **Annexure E**) and a thixotropic jelly, to prevent water penetration and protect the fibres against shock. Where applicable, filler elements are manufactured with Yellow PE to the same outer diameter as the loose tubes.

7.1.2 The elements are S-Z stranded around an all-dielectric central strength member and the formation retained with binders. To prevent the ingress of water, the design of the cable core is based on "part filled" technology, water blocking yarns are placed over the central strength member, and a water blocking material over the cable core.

7.1.3 Finally, an orange HDPE is applied as outer sheath.

7.1.4 A typical duct cable is shown in **Figure A1**.

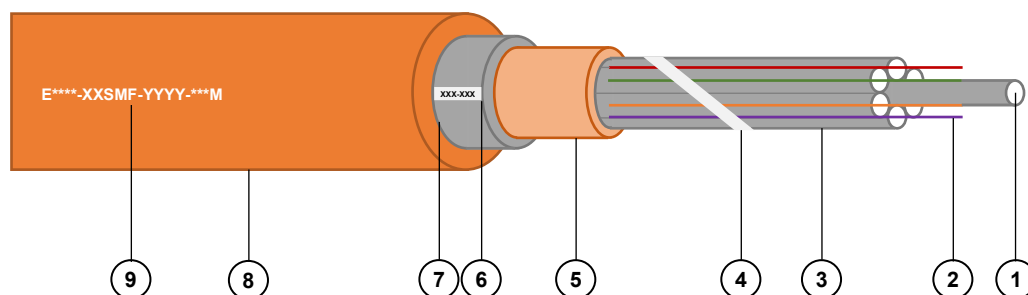


Figure A1: 1. Central strength member, 2. Fibre, 3. Loose Tube, 4. Binder tape, 5. High Strength Yarn, 6. Identification Tape, 7. High Strength Yarn, 8. Outer High Density Polyethylene Sheath-Orange, 9. Sheath Marking.

7.1.5 The offered cables shall be completely metal free and shall comply with IEC-60793 and IEC-60794.

7.1.6 It is preferred that the cables be part of or become part of the standard product range produced by the manufacturer.

7.1.7 The optical fibre cable as specified shall have single mode optical fibres in accordance with ITU-T Recommendation G.652D.

7.2 Optical Fibre Duct Cable Requirements

7.2.1 The clause sets forth the requirements for moisture exclusion:

- (1) As the cable may be subjected to total water immersion, the cable shall comply with the requirements for water penetration specified in Clause 25, Method-F5B of IEC60794-1-2 to prevent the ingress of moisture and other impurities to the optical fibres.
- (2) Dry core water blocking techniques shall be used for all cables.

7.2.2 The configuration of the cable shall be such that it is arranged in tubes of up to twelve fibres per tube. Filler elements will be used as required.

7.2.3 Cable Sheathing

- (1) The cable sheath shall be orange High-Density Polyethylene (HDPE), type PS4 in accordance with SANS 1411-7:2003 and shall be resistant to ultraviolet radiation with sheath nominal thickness ≥ 1.6 mm, unless otherwise stated in **Schedule A**.

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- (2) The entire cable shall consist of electrically insulating material.
- (3) The cable "manufacturers" name shall be embossed on the cable. Cable marking shall be hot foil printing in white on the outer sheath of the cable and, in addition, shall have the following text at one metre intervals (E**** contract number, XXSMF represents the single mode fibre count, YYYY represents the year of manufacture, ****M represents the metre marking). The markings are to be legible and indelible and shall not reduce the effectiveness of the cable in resisting insect and termite attack.

7.2.4 The following requirements for cable design shall be observed:

- (1) The cable is to be of non-metallic all dielectric construction.
- (2) The cable will incorporate a central non-metallic strength member and helically stranded aramid yarn as strength elements.
- (3) The optical fibres shall not be constrained firmly against other fibres, strength members, moisture barrier compound or any other cable components in order that the fibre strain is de-coupled from the strain in other components when the cable is under tension.
- (4) The construction type shall be "loose tube" and employ the reverse oscillating lay (ROL, S-Z) stranding technique on the tubes, which periodically reverses the rotation of stranding. The tube shall conform to the colour codes as specified in **Annexure F**.
- (5) Shall contain ripcords for easy sheath removal.

7.2.5 The cable mechanical requirements are listed as follows:

- (1) The cable must be able to withstand a directly applied long term crush loads of 1.2 kN per 100 mm without increase in optical attenuation for any fibre or any decrease in the integrity of the optical fibre cable over its designated lifetime. The test method to be followed is as per IEC 60794-1-E3.
- (2) The cable shall have a tensile strength in excess of 1.2 kN and tested as per test method specified in IEC 60794-1-2-E1.
- (3) The cable shall have a minimum bend radius of 15 times the cable outer diameter according to IEC 60794-1-11.
- (4) The Cable shall have an operating temperature range between 0°C to +50°C and shall pass temperature cycling tests according to IEC 60794-1-2-F1.

7.3 Optical Fibre Requirements

7.3.1 The optical fibres will be single mode fibres with the following characteristics:

- (1) The fibres shall be single mode fibres and the characteristics of each single mode optical fibre in the optical fibre cable will adhere to the ITU-T's recommendation G.652.D (IEC 60793-2 B1.1 SMF Type) as specified in **Schedule A**.
- (2) The secondary fibre coating is required to be a tight UV Acrylate coating and shall be easily removed by mechanical means for jointing purposes. Preference is likely to be given to fibres, which have a primary buffer coating of 250±15 µm low modulus UV, cured Acrylate material. Thus, Contractors are encouraged to offer prices for totally UV cured Acrylate coated fibres where possible. Contractors may offer more than one primary, buffer coating material. In such cases Contractors should provide as much information as possible regarding the physical, mechanical, and transmission performance of such fibres, with particular regard to the relative susceptibility to hydrogen degradation compared with UV Acrylate coated fibre.
- (3) The colours of individual fibres and tubes as well as other cable components shall allow for the unique identification of individual fibres within the cable. The fibre cores shall conform to the colour codes as specified in to ANSI/TIA/EIA-598.
- (4) The fibres shall not be jointed within any un-installed cable length (e.g. factory joints).

7.4 Drawings

7.4.1 Contractors shall provide detailed drawings of the cross-section of the items offered.

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8. Testing

8.1 Tests Standards

- 8.1.1 Cables and fibre cores shall be tested in accordance with the requirements of the relevant Standards listed.
- 8.1.2 The testing procedure (method statement) and device settings of any OTDR machine (or any other programmable device) that has been used by Contractor, shall be provided and approved by Employer's Agent (this is a hold point for testing).

8.2 Routine Testing

- 8.2.1 The attenuation of the fibre shall be tested using a 1310 nm and 1550 nm wavelength light source at one end of the fibre and an optical level metre at the other end.
- 8.2.2 Continuity shall be tested at 1310 nm and 1550 nm wavelength by measuring backscattered light using an Optical Time Domain Reflectometer (OTDR), which is adjusted to see the whole length of the fibre. This measurement shall be done from both ends of each fibre.
- 8.2.3 The overall attenuation and the OTDR traces shall be recorded and shall form part of the test certificates.

8.3 Testing of Overhead Optical Ground Wire (OPGW)

- 8.3.1 A type testing table of requirements is given by **Table A1**.

Table A1: Type testing requirements

No.	Test on Complete Cable	Test Intent / Objective	Optical Measurements Required?	IEC 60794-4-10:2014 Family Specification – OPGW Along Electrical Power Lines
1	Creep Test	Determine long-term tensile creep characteristics of cable	No	8.3.7
2	Stress-Strain Test	Determine stress-strain characteristics and the final modulus of elasticity (MOE) of cable.	No	8.3.3
3	Strain Margin/ Tensile Performance	Determine cable tension and strain at which the optical fibres start to elongate.	Yes	8.3.2
4	Tensile/ Breaking Strength	Verify that the actual (ultimate) tensile strength of the cable meets or exceeds the supplier's rated tensile strength (RTS).	No	8.3.4
5	DC Resistance	Verify that the actual DC resistance of the cable does not exceed the DC resistance stated by the supplier.	No	*
6	Sheave Test	Subject cable to a simulated action of being pulled over a number of sheaves during installation.	Yes	8.3.5
7	Crush Test	Subject cable to simulated crushing or clamping forces that could occur during installation or maintenance.	Yes	*
8	Bend Test	Subject cable to a bending action similar to what might be experienced during installation.	Yes	*
9	Twist/ Torsion Test	Subject cable to a simulated action of being pulled during installation.	Yes	*
10	Aeolian Vibration Test	Subject cable and hardware to Aeolian vibrations which can fatigue metal components of the cable and/or hardware at attachment locations.	Yes	8.3.6
11	Galloping Test	Subject cable and hardware to galloping motions. Fatigue or other damage can occur on the components of the cable, hardware, and/or to the structure.	Yes	8.3.8

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No.	Test on Complete Cable	Test Intent / Objective	Optical Measurements Required?	IEC 60794-4-10:2014 Family Specification – OPGW Along Electrical Power Lines
12	Short-Circuit Test	Subject cable to short-circuit conditions that represent field conditions. Damage can be inflicted to the cable strands through bird caging, loss of tensile strength, or melting or softening of non-metallic components because of excessively high temperatures.	Yes	8.3.11
13	Lightning Arc Test	Subject cable to lightning conditions that represent field conditions.	Yes	8.3.12
14	Water Ingress	Determine if the quantity of fluid blocking compound in is sufficient and uniformly distributed to inhibit water from migrating through the optical unit.	No	8.3.10
15	Seepage of Flooding Compound	Determine if the fluid blocking compound in the OPGW cable is vulnerable to flowing at elevated temperatures.	No	*
16	Temperature Cycling Test	Subject cable to extreme temperatures as may be experienced in the field.	Yes	8.3.9
17	Salt Spray Corrosion	Determine the effects of a controlled salt atmosphere on the cable.	No	*

* Test not included in list of Type Tests

8.3.2 Routine Tests

- (1) The optical fibre attenuation and continuity for each fibre of each cable drum length shall be measured and recorded prior to shipment from the manufacturing plant. The test results shall include date of test, drum number, drum length and names of test personnel.
- (2) The report should include details of the helix factor, the index of refraction, and the Rayleigh backscatter factor of the fibre cable used.

8.4 All Dielectric Self Supporting (ADSS) Optical Fibre Cable

8.4.1 Type Tests

(1) Graph

Contractors shall provide a graph of cable strain versus fibre strain.

(2) Results of Type Testing

Results of type testing previously carried out on the same ADSS type offered shall be provided at time of tendering.

(3) Breaking Load Test

Following completion of the stress/strain test, the tension shall be increased until breakage load and the load at which the ADSS or fitting began to yield under tension shall be recorded.

(4) Crushing Force Test

A sample of the optical fibre core shall be subjected to a lateral crushing force, which shall be slowly increased from zero. The transmission characteristics of the optical fibres shall be continuously monitored. A graphical plot of transmission loss versus lateral force shall be prepared. The lateral force shall be increased until the change in transmission loss of the optical fibres exceeds 0.1dB. The test method is as per IEC60794-1-E3.

8.4.2 Routine Tests

(1) Attenuation, Continuity and Records

The optical fibre attenuation and continuity for each fibre of each cable drum length shall be measured and recorded prior to shipment from the manufacturing plant. The test results shall include date of test, drum number, drum length and names of test personnel.

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8.5 Underground Optical Fibre Cable

8.5.1 Type Tests

(1) Results of Type Testing

Results of type testing previously carried out on the same underground type cable offered shall be provided at time of tendering.

(2) Breaking Load Test

The cable shall be tested in accordance with the method specified in IEC 60794-1-2-E1.

(3) Crushing Force Test

A sample of the optical fibre core shall be subjected to a lateral crushing force, which shall be slowly increased from zero. The transmission characteristics of the optical fibres shall be continuously monitored. A graphical plot of transmission loss versus lateral force shall be prepared. The lateral force shall be increased until the change in transmission loss of the optical fibres exceeds 0.1dB. The test method is as per IEC60794-1-E3.

8.5.2 Routine Tests

(1) Attenuation, Continuity and Records

The optical fibre attenuation and continuity for each fibre of each cable drum length shall be measured and recorded prior to shipment from the manufacturing plant. The test results shall include date of test, drum number, drum length and names of test personnel.

(2) Helix Factor, Index of Refraction and Rayleigh Backscatter Factor

The report should include details of the helix factor, the index of refraction, and the Rayleigh backscatter factor of the fibre cable used.

8.6 Tests after Delivery

8.6.1 The cables shall be subject to OTDR tests immediately after delivery by the Contractor. The Engineer reserves the right to reject all cables not in conformance with this Specification or the Contractor's guaranteed parameters stated in Schedule B. All rejected cables shall be replaced by the Contractor at the Contractor's expense.

8.6.2 Refer to the form: **Annexure B: ATTENUATION TESTING ON OPGW/ Optical Fibre Cable**

8.7 Test Certificates

8.7.1 Test certificates shall be supplied by the successful Contractor for all tests required by this Specification.

8.7.2 Payment under the Contract shall not become due and payable unless and until test certificates are received by the Engineer in accordance with the following:

(1) Type Test Certificates

All type tests shall be completed and certificates submitted as part of the tender response.

(2) Routine Test Certificates

Routine test certificates shall be submitted prior to the dispatch of the cable from the manufacturing plant.

(3) Tests After Delivery

Each drum delivered to site shall be tested and the Engineer issued with the results as laid out in this Specification as described in **Annexure B**.

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9. Risk Assessment

9.1 Manufacturer Risk Assessments

- 9.1.1 There is no requirement for the manufacturer to provide safety risk assessments for the items covered by this specification.

10. Quality Assurance

10.1 Purchasers Policy

- 10.1.1 It is the Purchaser's policy to procure goods, equipment and services from sources that demonstrate the ability to supply quality products.

10.2 Documentary Evidence

- 10.2.1 Documentary evidence shall be provided concerning the level of quality system certification associated with the Contractor and/or Manufacturer. This documentation shall include the Capability Statement associated with the Quality System Certification.

11. Samples

11.1 Production Samples

- 11.1.1 When requested, production samples of each item offered shall be submitted to assist in the evaluation of the offer. Each sample shall be delivered freight free, suitably packaged and labelled with the following information:
- (1) Name of Supplier and the Contract No.
 - (2) Contract item numbers.
 - (3) Any supporting data on features or characteristics.

12. Packaging and Marking

12.1 General

- 12.1.1 It is the appointed supplier's responsibility to ensure that the optical fibre cable is delivered to site free from damage. Storage, packaging, delivery to site and all other aspects of cable protection are the responsibility of the Contractor.
- 12.1.2 Optical fibre cables may be supplied on either timber drums or steel drums complying with the requirements of this Specification.
- 12.1.3 The standard guidelines for timber drums are as follows:
- (1) The conductor shall be supplied on returnable, strong, wooden drums provided with lagging of adequate strength, constructed to protect the conductor against any damage and displacement during transit, storage and subsequent handling and stringing operations in the field. The Contractor shall be responsible for any loss or damage during transportation handling and storage due to improper packing.
 - (2) The drums shall be suitable for spindle mounting and for letting off of the conductor under a minimum controlled tension in the order of 5 kN.
 - (3) The Contractor should submit their proposed drum drawings along with the tender.
 - (4) The Contractor shall not offer more than one length of the conductor on a single drum.
 - (5) All wooden components shall be manufactured out of suitable timber and be free from defects that may materially weaken the component parts of the drums. Wood preservative treatment shall be applied to the entire drum, with preservatives of a quality which is not harmful to the conductor.
 - (6) The flanges shall be of two-ply construction with a minimum thickness of 64 mm with each ply at right angles to the adjacent ply and nailed together. The nails shall be driven from the inside of the flange, punched and then clenched on the outer face. Flange boards shall not be less than the nominal thickness 32 mm $\pm$ 2 mm.

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- (7) There shall not be less than 2 nails per element. Where a slot is cut in the flange to receive the inner end of the conductor the entrance shall be in line with the periphery of the barrel.
- (8) The wooden battens used for making the barrel of the conductor drum shall be of segmental type. These shall be nailed to the barrel supports with at least two nails per end. The batten shall be closely butted and shall provide a round barrel with a smooth external surface. The edges of the battens shall be rounded or chamfered to avoid damage to the conductor.
- (9) Threaded barrel bolts shall be used to reinforce the drum barrel. The flanges shall be drilled to accommodate the spindle plates and the barrel supports bolts. The barrel bolts shall be threaded over a length on either end, sufficient to accommodate washers, spindle plates and nuts for fixing flanges at the required spacing.
- (10) The nuts on the bolts shall stand proud of the flanges. All the nails used on the inner surface of the flanges and the drum barrel shall be counter sunk. The ends of the barrel shall generally be flushed with the top of the nuts.
- (11) The inner face of the flanges and drum barrel surface shall be painted with bitumen-based paint.
- (12) Before reeling, double corrugated cardboard or thick bituminous water proof paper shall be secured to the drum barrel and to the inside of flanges of the drum by means of a suitable commercial adhesive material. The paper should be dried before use. After reeling the conductor, the exposed surface of the outer layer of conductor shall be wrapped with water proof thick bituminous paper.
- (13) A minimum space of 75 mm for conductor shall be provided between the inner surface of the external protective lagging and outer layer of the conductor.
- (14) The nuts on the barrel bolts shall be tack welded on one end. On the other end, a spring washer shall be used.
- (15) A steel collar shall be used to secure all barrel bolts. This collar shall be located between the washers and the drum and secured to the central steel plate by welding.
- (16) The conductor ends shall be properly sealed and secured to the side of one of the flanges to avoid loosening of the conductor layers during transit and handling.
- (17) As an alternative to wooden drums, the Contractor/Contractor may also supply the conductors on non-returnable painted steel drums. Steel drums shall be appropriately painted to guard against corrosion. After preparation of the steel surface, one coat of suitable primer shall be applied and thereafter a synthetic enamel paint.

12.1.4 Optical fibre cables shall be supplied on drum sizes and in the lengths as required in the Technical Schedules, and as per the stringing requirements.

12.1.5 The cable shall be wound in such a way as to preclude the possibility of chafing or damage to the cable during reeling and transport. The reeling tension shall be as low as possible, being only as high as that required to minimise movement of cable between adjacent layers.

12.2 Drum Lagging

12.2.1 The cable shall be protected by external lagging to ensure that it is delivered undamaged whilst giving due consideration to the methods and distance of transportation and handling.

12.2.2 Each batten shall be securely nailed across grains as far as possible to the flange, edges with at least 2 nails per end. The length of the nails shall not be less than twice the thickness of the battens. The nails shall not protrude above the general surface and shall not have exposed sharp edges or allow the battens to be released due to corrosion.

12.2.3 Outside the protective lagging, there shall be minimum of two binders consisting of hoop iron/ galvanized steel strap. Each protective lagging shall have two recesses to accommodate the binders.

12.2.4 Sheet form wrapping alone is NOT acceptable.

12.3 Drum Durability

12.3.1 All drums must be of suitable quality and robustness to withstand a minimum of twenty-four months (24) exposure

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to all types of weather conditions during outdoor storage, without deterioration.

12.4 Drum Treatment

- 12.4.1 Drum surface treatment to protect against weather, the environment, galvanic action, and corrosion is required. FAO International Standard for Phytosanitary Measures (ISPM) No. 15 must be met.
- 12.4.2 Suppliers shall state the type of surface treatment applicable to drums for each item. FAO "Guidelines for regulation of wood packing material in international trade" of 2002 with modifications 2006 must be met for imported drums.

12.5 Marking of Drums

- 12.5.1 Standard Marking Guidelines: The marking of information on the cable drum shall provide the following information indelibly and legibly marked directly on the flanges:
- (1) Contract number.
 - (2) Purchasing order number.
 - (3) Manufacturer's traceability number – derived from Manufacturer's first letter, hyphen, batch number, hyphen, drum number for this batch.
 - (4) Weight of drum, size and length of conductor/cable.
- 12.5.2 Letter Size and Location: Marking at least 25 mm high shall be located on both outside flange surfaces near the spindle.
- 12.5.3 Drums shall be marked with the preferred direction of rolling and shall be rolled according to this directional marking.
- 12.5.4 The following information shall also be provided:
- (1) The type of cable i.e. All Dielectric Optical Fibre Cable /OPGW/Duct Fibre Cable.

12.6 Fixing of Cable End

- 12.6.1 The inner end of the cable shall be secured to the drum to ensure that the end will not flick off the drum barrel when the cable is being run out.

12.7 Quarantine Requirements

- 12.7.1 Should the items offered be supplied from overseas manufacturers, then it is mandatory that all conditions and inspections required by the Engineer be met and that all these costs be included in the tendered price. In particular, timber crates must be fumigated with methyl bromide with a concentration of 48 grams per cubic metre for 24 hours at 21°C. The supplier shall ensure that the procedure does not produce any deleterious effects to the cable/conductor or the drums.

13. Service Performance

- 13.1.1 Suppliers shall state:
- (1) The period of service achieved by the items offered within service conditions as stated **Schedule A**;
 - (2) South African electricity supply authorities who have a service history of the items offered; AND
 - (3) Contact names and phone numbers of relevant employees of those supply authorities who can verify the service performance claimed.

14. Reliability

14.1 Service Life

- 14.1.1 Suppliers are required to comment on the reliability of the cables and the performance of the materials offered for

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a service life of 25 years under the specified system and environmental conditions.

14.2 Evidence in Support of Reliability

- 14.2.1 Such data to be submitted shall include evidence in support of the reliability and performance claimed including information on Failure Mode and Effect Analysis.

15. Training

- 15.1.1 Training material in the form of drawings, instructions and/or audio visuals may be required for the items accepted under the offer.
- 15.1.2 Contractors shall state the availability of training materials which should include but is not limited to the following topics:
- (1) Handling
 - (2) Storage
 - (3) Application (particularly in areas of heavy coastal pollution)
 - (4) Installation
 - (5) Maintenance
 - (6) Environmental performance
 - (7) Electrical performance
 - (8) Mechanical performance
 - (9) Disposal

16. Environmental

16.1 Considerations

- 16.1.1 Suppliers are required to comment on the environmental soundness of the design and the materials used in the manufacture of the items offered. In particular, comments should address such issues as recyclability and disposability at the end of service life.

17. Information to be Provided

17.1 Specific Technical Requirements

- 17.1.1 The specific technical requirements for the items offered shall be as stated in **Schedule A** of this specification. The supplier shall provide all details of cable offered in Schedule B and shall guarantee such data.

17.2 Checklist of Supporting Documentation

- 17.2.1 **Annexure D** details a checklist of supporting technical documentation which is required to be submitted with the offer.

17.3 Fibre Information

- 17.3.1 Contractor is required to supply the following fibre characteristics:
- (1) A graph of attenuation versus wavelength over the range of 700 nm to 1700 nm for single mode fibres.
 - (2) A typical graph of fibre attenuation for the 1310 nm and 1550 nm wavelength for single mode fibres for the temperature range of 5°C to 75°C.
 - (3) Details for the strength of the fibres.
 - (4) A graph of attenuation verses cable strain for each cable offered.

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(5) Information on the chromatic dispersion co-efficient in ps/(km.nm) with respect to zero dispersion wavelength in the region of 1310 nm and 1550 nm for single mode fibre.

(6) Information on the Dispersion Slope at Zero Dispersion Wavelength in ps/(nm-m).

17.3.2 Contractors shall provide information regarding the physical, mechanical, and transmission performance of fibres, with regard to the relative susceptibility to hydrogen degradation.

17.3.3 Fusion splicing techniques shall be provided by the installation contractor. Contractors shall provide details of their fibre's performance with respect to jointing techniques (arc fusion splicing), preferably in the form of histograms showing minimum obtainable splice losses.

17.4 Information on Cable

17.4.1 Full details of the water blocking compound shall be supplied by the Contractor, including the method of removing the compound prior to cleaving and splicing. This clause shall form part of the requirements for moisture exclusion.

17.4.2 Cable Sheathing: The Contractor must include, in the tender document, information detailing the design and performance of the sheath and jacket of the cables offered to demonstrate that the cable is adequate for a 25-year service life time. The information should include:

- (1) The material used as the outer sheath.
- (2) Effectiveness of resisting pest attack.
- (3) The thickness of the outer sheath.
- (4) Resistance to environmental stress cracking and thermal and ultraviolet radiation ageing.

17.4.3 The Contractor is to provide details of the design of the cable. The documentation provided will include a cross-section of the cable, nominating the materials used on the drawing and any other relevant information.

17.4.4 The Contractor shall supply a full listing of the material components (and material properties) used in the cable with details on toxicity and safe handling of the materials.

17.4.5 Contractors are required to supply details of the colour of fibres.

17.4.6 Contractors are required to supply details of the colour of fibres tubes.

17.4.7 The Contractor will supply results of vibration resistance tests.

17.4.8 The Contractor will supply information to support a cable service life time of 25 years for the environmental conditions listed in Clause 16.0. Details as to potential damage to fibres caused by cable materials with particular reference to hydrogen producing agents, shall also be included.

17.4.9 An aerial optical fibre cable must have sag-strain characteristics such as to enable its installation onto existing power line structures while maintaining clearances to low and high voltage mains (lines) and other statutory clearances. The Contractor shall supply stringing chart(s) or tables showing optical fibre strain and sag-tension information for the following conditions:

- (1) Range of spans 100-350 m in steps of 20 m.
- (2) Range of cable tensions 0-100% of the maximum recommended cable tension.
- (3) Range of temperatures -5°C to +75°C in steps of 5°C.
- (4) Contractor to indicate the constant horizontal tension (@ 15°C no wind).
- (5) The Contractor shall supply details of all assumptions used in calculating stringing chart(s) or tables.

17.5 Cable Installation Information

17.5.1 The Contractor will nominate any special requirements that the Engineer will need to adhere to during the installation of the fibre to ensure that the cable is installed damage free and the lifetime of the installation is not unnecessarily reduced.

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PART B: SPECIFICATION FOR INSTALLATION OF OVERHEAD OPTICAL GROUND WIRE (OPGW)

1. Introduction

1.1 Purpose

1.1.1 The aim of this part of the specification is to specify the methods used for installation of OPGW.

1.2 General

1.2.1 Optical Ground Wire (OPGW) was developed to provide a large capacity telecommunications system utilizing overhead power transmission lines. Serving the additional purpose of an overhead ground wire (earthwire/ Shieldwire), the OPGW is typically constructed of a combination of aluminium clad steel strands and aluminium alloy strands or all aluminium alloy strands, stranded with stainless-steel tubes or a fibre unit (core) which contains optical fibres. OPGW can be installed using the basic stringing methods currently employed for overhead ground wires, with minor variations.

1.2.2 This part of the specification outlines basic installation methods for existing and newly constructed transmission lines. The installer should be thoroughly familiar with the installation of conventional overhead ground wire and conductors. Additional information can be obtained from the SANS 10280-1 Overhead Power Lines for Conditions Prevailing in South Africa.

1.3 Scope

1.3.1 This document covers all the activities performed for the installation of OPGW, including transport, accessory assembly, verification of optical transmission characteristics and final certification.

2. Normative and TE References

IEC 61284	Overhead Lines Requirements and Tests for Fittings
Cigré TB 746	Technical Brochure: Design, deployment and maintenance of optical cables associated to overhead HV transmission lines
SANS 10280-1	Overhead power lines for conditions prevailing in South Africa- Part 1: Safety
TE_CNINSTR009	Technical Instruction- Optical Fibre Cable Testing

3. Preparation Procedures

3.1 Survey of the line

3.1.1 Prior planning for installation of the OPGW is performed by surveying the line, taking into account various parameters such as: the length of drum and splice location/position.

3.1.2 The OPGW drum lengths are determined based on the following considerations:

- (1) Position of the tension towers, tower access,
- (2) Distance between supports and crossing with other lines,
- (3) Roads, railways routes, services and other obstacles.

3.1.3 The position of the splices depends on the maximum available length of OPGW, on the position of the towers and the tower access. The splice locations of the OPGW conductor must be planned to allow for splicing of the optical fibres. The drum lengths will be engineered to locate the conductor splices at predetermined towers on each end of a stringing section.

3.2 Loading, Transport and Offloading

3.2.1 Rules and Guidelines

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- (1) OPGW drums should always be transported and handled in an upright position. Never lay a drum of conductor on its side.
- (2) The drums must be offloaded, or moved in a controlled manner such that the drum remains in vertical position and the sides of the drum are not damaged by the offloading process.
- (3) Under no circumstances should the drum be rolled off the delivery or transport vehicle.
- (4) The drums can be moved by rolling a short distance ensuring that there are no objects that may damage the staves. The direction of rotation should follow the instruction mark on the drum.
- (5) After transport and offloading, the drums must be inspected to verify that they have not been damaged and that none of the staves or safeguards are broken.
- (6) Each drum of OPGW must be tested prior to and after installation, to ensure that fibre damage has not occurred during shipping and/or stringing operations, using an OTDR tester on each fibre.
- (7) The ends of the OPGW must be sealed to prevent water ingress.
- (8) All conductor protective packaging (wood lagging or flex wrap) must remain in place on all drums until placed on pay-out racks and rack is positioned for conductor stringing.
- (9) The conductor drums should be transported with the inner tail securely connected to the outside of the drum flange. This connection should be *loosened, but not removed*, prior to stringing.

3.3 OPGW Installation Preparation

3.3.1 Care must be taken to avoid damaging the OPGW during handling and stringing operations. Avoid sharp bends to the conductor and take precautions to prevent crushing the OPGW during placement. The transmission quality of the optical fibres can potentially be degraded if the OPGW is subjected to excessive pulling tensions or excessively small bend diameters.

3.3.2 General Considerations

- (1) Always observe the recommended values for maximum stringing tensions and minimum bend radius. More information about these values can be obtained from manufacturer's data sheets.
- (2) By adhering to (1) above, this allows the inner layers of conductor to adjust themselves to the varying tensions seen during installation. As the conductor makes these adjustments, the inner tail may extend requiring periodic attention.
- (3) A controlled tension stringing method of installation is required.
- (4) Ordinary stringing equipment can be utilized as if installing standard overhead ground wire.
- (5) Suitable equipment includes pullers, tensioners, drum winders, and stringing blocks. **Figures B1 and B2** illustrate typical stringing setups.

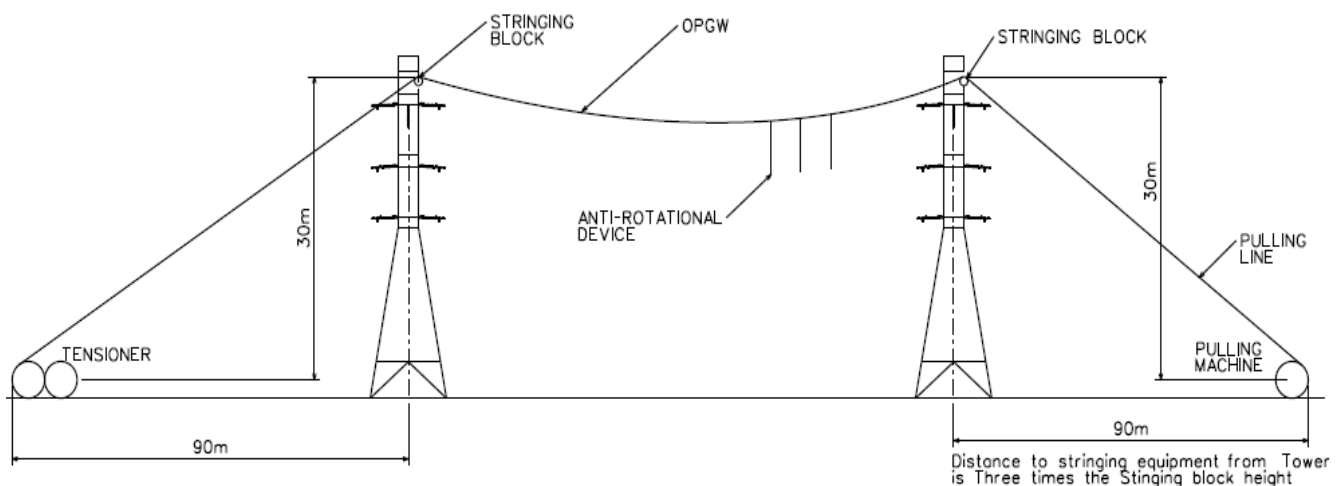


Figure B1: Typical Stringing Arrangement

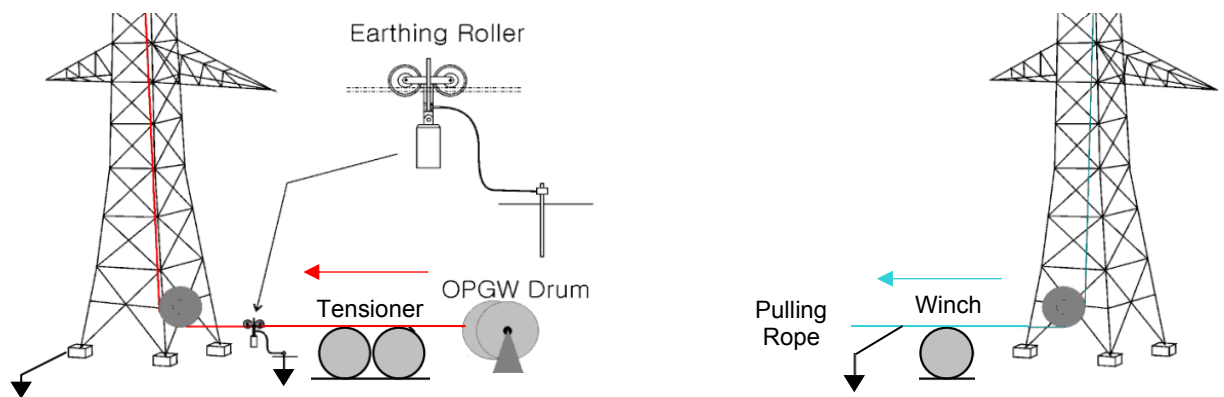


Figure B2: Typical Stringing Arrangement – Back Pull

- (6) The tensioner as well as the puller should be placed aligned with the conductors. The maximum acceptable deviation angle α is 30° , illustrated in **Figure B3**.

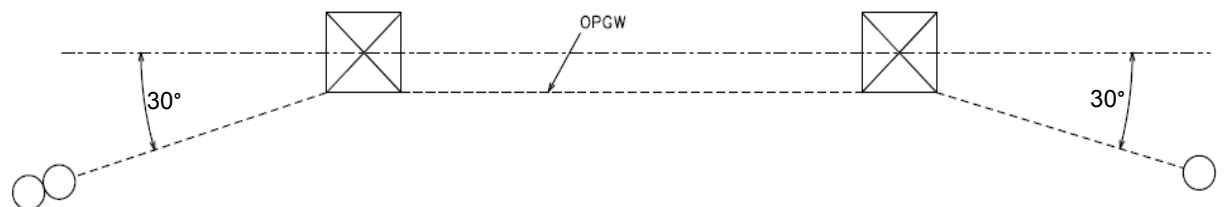


Figure B3: Typical Stringing Setup- Maximum Deviation Angle α

- (7) After installing dead ends, the free end of the OPGW is secured down the towers to the ground for splicing.
- (8) The length of the free conductor should be at least the tower height, plus an additional 20 m to accommodate splicing. After stringing, this excess conductor must be coiled and temporarily stored above the anti-climb barrier on the tower until splicing occurs.
- (9) The OPGW attachment hardware, including dead ends, suspension clamps, and wire fittings such as grounding clamps must be designed to provide the necessary holding strengths and prevent deformation of the fibre unit which could potentially damage the optical fibres.

4. Stringing

4.1 Typical Stringing Setup Guidelines

- 4.1.1 Maximum OPGW recommended stringing tension is 20% (at tensioner) of the rated breaking strength.
- 4.1.2 The minimum bull-wheel diameter for tensioners is $70 \times D$. (Where D represents the nominal diameter of the OPGW). For larger diameter OPGW conductors where $70 \times D$ exceeds 1.5 m, a ~1.5 m bull wheel may be used.
- 4.1.3 The recommended stringing sheave (root) diameter is $40 \times D$. (Where D represents the nominal diameter of the OPGW). This is based on a sheave through angle of 45° and maximum stringing tension (at tensioner) of 20% of the rated strength of the OPGW.
- 4.1.4 The minimum bending radius after installation (static) for the OPGW is $15 \times D$. (Where D represents the nominal diameter of the OPGW).
- 4.1.5 The minimum bending radius during installation (dynamic) for OPGW is $20 \times D$. (Where D represents the nominal diameter of the OPGW).

NOTE: Based on actual OPGW size, care must be taken when bending the OPGW to avoid kinking the strands and, therefore, damaging the optical fibres contained within the tubes.

- 4.1.6 The minimum permanent bending radius for the stainless-steel tube is $45 \times d$. (Where “d” represents the diameter of the stainless-steel tube).

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- 4.1.7 The minimum permanent bending radius for plastic buffer tubes is 80 mm unless otherwise stated in Schedule B.
- 4.1.8 The minimum permanent bending radius for the optical fibres is 38 mm unless otherwise stated in Schedule B.
- 4.1.9 The swing angle of the stringing block shall be controlled with respect to the swing angle of the OPGW stringing plane to help prevent the conductor from riding out of the traveller or excessive twisting during installation. The conductor should travel through the lowest part of the groove.
- 4.1.10 The following are minimum diameters of stringing blocks at:

(1) Terminal structures

The minimum stringing (sheave) block diameter (root) of $40 \times D$ (where "D" represents the diameter of the OPGW) is considered satisfactory if the pulling line slope is at least three times horizontal distance to one times vertical distance from the traveller to the site and the stringing tension does not exceed 20% of the OPGW's rated breaking strength.

(2) Suspension and angle structures, the following requirements shall be observed:

- (a) For suspension structures (line angle=0°) and stringing angles of 20° or less, a minimum sheave root diameter of $30 \times D$ is acceptable.
- (b) For stringing angles between 20° and 45°, a minimum sheave root diameter of $40 \times D$ is required.
- (c) For stringing angles between 45° and 60°, a minimum sheave root diameter of $50 \times D$ is required.
- (d) For stringing angles greater than 60°, a minimum sheave root diameter of $60 \times D$ is required.

4.2 Guidelines and Procedures

- 4.2.1 Stranded wire pulling lines are generally used to pull OPGW, although suitable nylon ropes can also be employed. In either case, the line must be rated to withstand the required stringing tensions. A stranded wire pulling line should have the same lay direction as the OPGW to help resist the tendency to rotate under stringing load.
- 4.2.2 If an existing overhead ground wire is to be removed, this may be used as a pulling line for the new OPGW. A visual inspection must be made of the existing ground wire to be sure it is in suitable condition for use as a pulling line. If there is any concern about the ability of the existing overhead ground wire to withstand the stringing tensions, it should be pulled out and replaced with a pulling line.
- 4.2.3 A bull-wheel type tensioner with round (not "V" type) polyurethane lined contact grooves must be used unless otherwise approved by the Engineer. The tensioner should have two bull wheels, each with multiple grooves to minimize conductor damage. The tensioner should be capable of maintaining the required tensions at various pulling speeds. Positive braking systems are necessary for pullers and tensioners to maintain the tension when hauling is stopped. The minimum diameter of the bull wheels should not be less than $70 \times D$ (D is the diameter of the OPGW).
- 4.2.4 The OPGW must be reeved (threaded) through the bull-wheel tensioner properly. Left-hand lay OPGW (typically procured from the USA) is reeved from right to left. Right hand lay OPGW (typically international, excl. USA), is reeved from left to right. A thorough explanation of the reeving process can be found in IEEE Std 524-2003. This arrangement is necessary to avoid any tendency to loosen the outer layer of the OPGW strands and to avoid induced torque during installation.
- 4.2.5 The tensioner must be equipped with a dynamometer.
- 4.2.6 The OPGW drum shall be placed directly in line with the tensioner. The distance from the drum to the tensioner should be at least 7.5 m. The OPGW shall not be permitted to scrape the drum flanges while being played out.
- 4.2.7 Both the braking device and the puller shall be suitably connected to the ground by a system of moveable rollers. This also applies to the OPGW cable and the pulling cable (if it is a metal).
- 4.2.8 The OPGW drums are not designed to withstand the braking forces present during stringing. Direct tensioning of the OPGW from the conductor drum is not acceptable. Back tension on the drum should only be enough to keep the conductor properly seated in the tensioner grooves and to prevent overshooting and bird-caging.
- 4.2.9 Two basic types of pulling machines are recommended for tension stringing. These are either drum type or bull-wheel type pullers. Positive braking systems are required in either case. On a drum type puller, the pulling line is taken up directly onto the drum. On the bull-wheel type, the line is threaded onto two bull-wheels, much like the

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tensioner, and onto a self-winding drum.

- 4.2.10 The puller must also be equipped with a dynamometer with automatic disconnection in case of over tension on the OPGW.
- 4.2.11 Stringing blocks, sometimes referred to as travellers or running-out blocks, must be mounted on the structure at the OPGW attaching point in the normal manner.
- 4.2.12 The stringing blocks should have neoprene lined grooves. The linings should be in good condition and adhere to the block. Minor rough areas can be sanded to ensure that the lining is smooth.
- 4.2.13 Uplift rollers (which attach to the installation sheave wheel) or hold-down blocks (which are separate blocks) need to be placed where uplift of the pulling line is likely to occur (due to its higher tension/weight ratio than the conductor). This will typically occur going up inclines or at a low point in a section. These devices must also have a break away feature in the event of fouling or incorrect installation,
- 4.2.14 The tensioner and puller should be positioned for a 3:1 ratio to the stringing block on the first structure adjacent to the equipment (see **Figure B1**). The tensioner should be placed in line with the first two structures (or first span) of the pull. Likewise, the puller should be placed in line with the last two structures (or last span) of the pull. This minimises the deviation angle seen by the conductor during the installation process.
- 4.2.15 This minimum stringing block to the tensioner ratio (3:1) will help prevent deformation of the fibre unit (stainless-steel tube), which protects the optical fibres in the OPGW.
- 4.2.16 The OPGW shall be attached to the pulling line (pilot wire) using a mesh wire grip, also referred to in the field as a “sock”, see **Figure B4**.

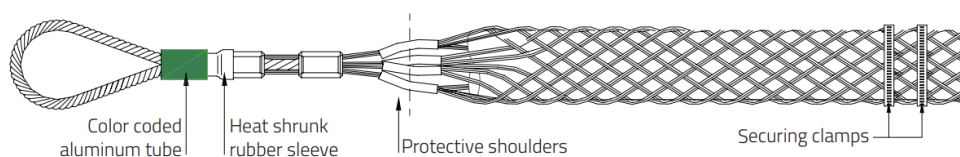


Figure B4: Mesh Wire Grip

- 4.2.17 A requirement for the use of an Anti-Rotational Device (ARD), also referred to in the field as a “gator” or “monkey tail”, (see **Figure B5**) depends largely upon the construction of the optical ground wire. This device is used to prevent the OPGW from twisting while being pulled. Variations of these devices have been successfully used. For conductors with helically stranded stainless-steel tubes or designs with two layers of wires, an ARD may or may not be required. A confirmation as to whether or not one of these devices is needed for the particular application must be obtained from the conductor manufacturer.

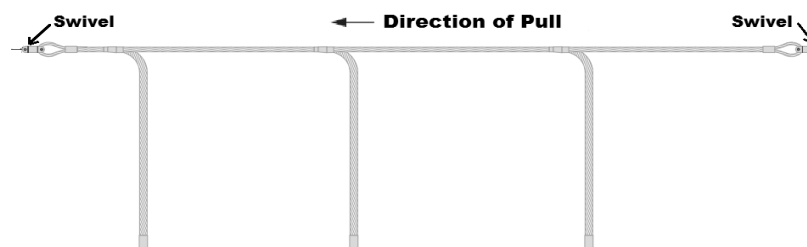


Figure B5: Anti-Rotational Device

- 4.2.18 If confirmation regarding the need to use an ARD cannot be obtained from the conductor manufacturer, the conservative approach must be used and the installation must be done with the use of an ARD. For conductors constructed with a stainless-steel tube in the centre of the conductor or single layer conductors, an anti-rotational device is always a requirement.
- 4.2.19 If the ARD fails to prevent conductor rotation or if the ARD is wrapping around the OPGW, a stiffer or heavier device

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is required. The weight and length of the ARD will depend upon the construction of the optical ground wire.

- 4.2.20 The ARD attaches to the OPGW with a mesh wire grip and swivel. The grip must be appropriately sized for the OPGW diameter and pulling tensions.
- 4.2.21 The weight of the ARD shall be high enough to prevent OPGW conductor rotation. The minimum values recommended for each counterweight are as follows:
- (1) Spans 300 m and below - 12 kg
 - (2) Spans 300 m to 700 m - 15 kg
 - (3) Spans above 700 m - 20 kg
- 4.2.22 For Installation lengths of longer than 4000 m these values should be increased by 5 kg.
- 4.2.23 After the counterweights have been installed, they should not be removed until the conductor is secure and cannot rotate.
- 4.2.24 The OPGW must be kept under constant tension during the stringing process to keep the line clear of both the ground and other obstacles that could cause damage to the conductor.
- 4.2.25 Do not cut the OPGW with ratchet cutters, or other types of tools that could crush the fibre unit. The use of a hacksaw will ensure the optical fibre units are free to move within the pipe.
- 4.2.26 During stringing, the first few metres of OPGW may elongate, and this will prevent unnecessary strain on the optical fibres.
- 4.2.27 It is important to monitor the tensions and ensure that excessive tension is not applied as the OPGW passes from the drum to the tensioner.
- 4.2.28 Stringing requirements for this specification are given in **Table B1**.

Table B1: OPGW stringing requirements

Item	Requirements
Minimum Bull-Wheel Diameter:	70 x D (D is the OPGW diameter). For larger diameter OPGW where 70 x D exceeds 1.5 m, a 1.5 m bull-wheel may be used.
Recommended Stringing Block Diameter	40 x D
Minimum Conductor Bend Radius During Installation:	20 x D (Dynamic); After Installation (Static): 15 x D
Maximum Stringing Tension	20% OPGW's Rated Breaking Strength ^(note 2)
Maximum Pulling Speed	40 meters per minute or 2.4 km per hour ^(note 3)
Minimum distance from puller and tensioner to the stringing block:	3:1 Ratio
Total number of spans in each stringing section:	Typically, 20 to 30 ^(note 1)

NOTES:

¹The maximum number of spans is included as a reference only; since this will vary considerably due to differences in terrain, span lengths, line angles, etc...

²The stringing tension is always measured at the tensioner side. The maximum stringing tension must be a half of the maximum sagging tension and never exceed 20% of Rated Breaking Strength of the OPGW.

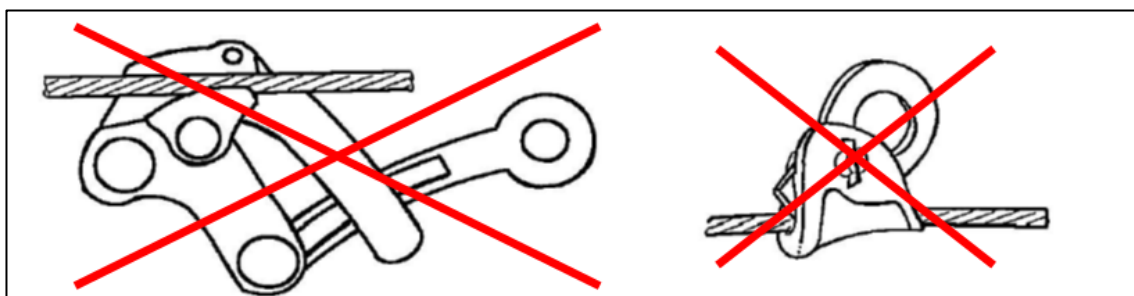
³The speed of stringing at the beginning is around 5m/min until the OPGW reaches the first tower. Once it passes through the sheave at the first tower, the speed can be raised up to 30m/min until the next tower sheave where the speed must be reduced to around 5m/min again. The maximum speed of stringing can vary, depending on the topology of the power lines, angles and the types of the towers, but should be no more than 40m/min. Some of the manufacture manuals allow an increase of speed up to 60m/min. This must be approved by the Engineer on a case by case basis.

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5. Sagging

5.1 Methodology

- 5.1.1 The methods and procedures for sagging the OPGW are the same as those for overhead phase conductors. For determining sags, the installer must use the sag-tension design information provided by the Design Engineer. The **temperature, sag and tension** must be recorded at the time of regulation.
- 5.1.2 A temporary fully rated pre-formed guy grip is installed on the OPGW for tensioning. The grip must be designed to hold the OPGW without damage, and in particular not pinch the conductor or crush the stainless-steel tube.
- 5.1.3 Some types of gripping devices that might damage the OPGW such as the Chicago grip or Kito grip are strictly prohibited for use on OPGW. **Figures B6 and B7** illustrate unsatisfactory come-a-long designs for use on OPGW.



Figures B6 and B7: Chicago Grip – Unsatisfactory and Kito Grip – Unsatisfactory

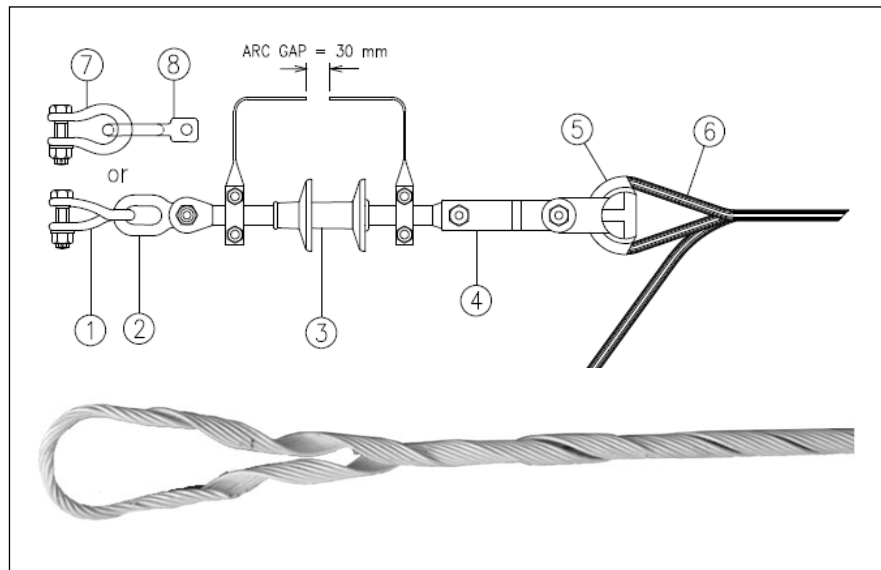
6. OPGW Components

6.1 Hardware and Accessories

- 6.1.1 Hardware/accessories are considered fittings that are permanently in direct contact with the OPGW, these include:
- (1) Tension Fittings.
 - (2) Suspension Fittings.
 - (3) Earthing Fittings.
 - (4) Clamps, such as:
 - (a) Down lead clamps used to fasten the OPGW to structure members on its path down to the splice box.
 - (5) Vibration Protection Fittings, such as:
 - (a) Vibration Dampers.
 - (6) Marker Fittings, such as:
 - (a) Aircraft warning markers.
 - (b) Bird flight diverters.
 - (7) Repair Rods, such as:
 - (a) Those devices used to repair damaged OPGW, such rods are capable of restoring the electrical conductivity and mechanical strength of the OPGW.
 - (8) Splice Boxes.

6.2 Tension Fittings

- 6.2.1 Dead-end fittings are installed on OPGW spans that terminate at splicing towers or ends of the system. Dead ends are also used at angle structures when the angles are too great to use suspension clamps. Suspension clamps are normally used at the remaining towers. An OPGW pre-formed wire wrap, for a strain fitting, is illustrated in **Figure B8**.



- 1 – Twisted Shackle
- 2 – Tongue Oval-eye
- 3 – Composite Insulator
- 4 – Cranked Extension
- 5 – Thimble Clevis
- 6 – Dead-end Preformed Wire Wrap with Protective Rods
- 7 – Straight Shackle

Figure B8: OPGW Strain Assembly and Pre-Formed Wire Wrap for Dead-End

Table B2: Type Tests for Accessories/Hardware – Tension Clamps / Dead-end Clamps

Item No.	Test on Hardware/ Accessories	Test Intent / Objective	IEC 61284-2009 Overhead lines – Requirements and tests for fittings
1	Mechanical Damage and Failure Load Test	Verify the manufacturer's strength rating of the hardware.	11.5.2
2	Magnetic Losses Test	Ascertain the magnetic losses of the hardware.	12
3	Tensile Test	Simulate performance under sagging and conditions of tensile load.	11.5.1
4	Aeolian Vibration Test	Subject cable and hardware to aeolian vibrations that can fatigue metal components of the cable and/or hardware at attachment locations.	*
5	Fault Current	Fault currents due to system short circuits in field conditions are simulated to determine the reaction of the hardware under forces of high current electrical surges.	*
6	Crush Test	Verify that the OPGW cable is not exposed to excess damage from crush upon initial installation of hardware.	*
7	Galloping Test	Subject cable and hardware to galloping motions. Fatigue or other damage can occur on the components of the cable, hardware, and/or to the structure.	*
8	Corrosion Test	Subject the hardware to an accelerated salt fog corrosion test that may be experienced in the field.	*

* Test not included in list of Type Tests in IEC 61284

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6.3 Suspension Fittings

- 6.3.1 The design of the suspension clamp must be of the helically attached elastomer suspension (HAES) type, which uses preformed helical rods (PFR) with an elastomer lining mounted over the OPGW, see **Figure B9**.

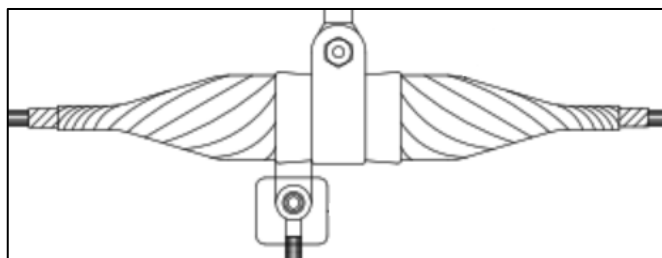


Figure B9: OPGW Suspension Clamp

Table B3: Type Tests for Accessories/Hardware – Suspension Clamps

Item No.	Test on Hardware/ Accessories	Test Intent / Objective	IEC 61284 Overhead lines – Requirements and tests for fittings
1	Mechanical Damage & Failure Load Test / Vertical Load Test	Verify the supplier's strength rating of the hardware.	11.4.1
2	Slip Test / Unbalanced Load Test	Subject suspension hardware to an imbalance in tensile loading on either side of the suspension hardware to ensure performance requirements.	11.4.2 or 11.4.3
3	Turning Angle or Line Angle Test	Subject suspension hardware to increasing tensile loads at the maximum recommended line angle of the suspension hardware to ensure performance requirements.	*
4	Aeolian Vibration Test	Subject cable and hardware to Aeolian vibrations that can fatigue metal components of the cable and/or hardware at attachment locations.	*
5	Fault Current Test	Fault currents due to system short circuits in field conditions are simulated to determine the reaction of the hardware under forces of high current electrical surges.	*
6	Galloping Test	Verify that the OPGW cable is not exposed to excess damage from crush upon initial installation of hardware.	*
7	Corrosion Test	Subject cable and hardware to galloping motions. Fatigue or other damage can occur on the components of the cable, hardware, and/or to the structure.	*
8	Crush Test	Subject the hardware to an accelerated salt fog corrosion test that may be experienced in the field.	*

* Test not included in list of Type Tests in IEC 61284

6.4 Bolted Clamps

- 6.4.1 Bolted clamps may include bonding (grounding) clamps, down lead clamps, clamps of warning markers, etc... Clamp grooves should be closely matched to the OPGW's diameter such as to avoid any crushing that might lead to a deformation of the optical unit and impair the optical performance.
- 6.4.2 Bolt tightening torques should be controlled within tight limits to avoid excessive clamping forces. Warning markers may be installed over armour rods to protect the OPGW from excessive contact pressure exerted by bolted clamps.

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Table B4: Type Tests for Accessories/Hardware – Bolted & Miscellaneous Clamps

Item No.	Test on Hardware/ Accessories	Test Intent / Objective	IEC 61284-2009 Overhead lines – Requirements and tests for fittings
1	Clamp Bolt Tightening Test	Verify that the cable is not damaged when hardware torqued to supplier's recommended value.	11.4.5 or 11.5.4
2	Corona and RIV, Damper Fatigue, Crush, Corrosion, etc.	Corona and RIV: Determine RIV and corona performance of fittings. Test does not address permissible RI limits or specified corona extinction voltages or gradients which are set by regulations or utility practice. Others: as above.	14

6.5 Bonding Clamps

6.5.1 Bonding to ground clamps are used to ground OPGW to the tower by attaching to the tower bonding conductor. The bonding clamp is used in conjunction with a bonding conductor to provide a path to ground from the OPGW cable to the tower. It is necessary to ensure that the clamp used will not cause damage to the OPGW that could result in point attenuation increases. These can be caused by the fitting crushing the optical unit containing the fibres.

6.6 Vibration Dampers

6.6.1 Vibration dampers, (spiral type), may be used to absorb the conductor or cable vibrations. The number of dampers can change and is directly determined by the installation parameters, the environmental conditions, the distance between towers and the type of cable. A vibration study determines the number of dampers to be used and where they must be placed.

6.6.2 If vibration dampers are required for a span, these should be placed on the OPGW immediately after clipping in. Dampers may not be required at every structure; their locations will be specified by the Engineer.

6.6.3 During installation, the damper clamp will hang from the conductor in accordance with IEC Standards. Since it is self-supporting, the workers hands are free to tighten the bolt to the proper torque.

6.7 Marker Fittings

6.7.1 Marker fittings, such as marker balls and flags, are usually used to highlight the visibility of the line. They are used near road crossings, river crossings, in close proximity to airports and other case specific areas.

6.7.2 Flight path marker spheres have the following requirements:

- (1) Where required marker spheres shall be of a diameter of not less than 600 mm.
- (2) The marker spheres shall be supplied in two colours, Orange and White with the spacing between the Orange and white spheres and between the spheres and the supporting towers shall not exceed 30m.
- (3) Sphere clamps must be made of aluminium and adapt to the diameter of the conductor unless otherwise approved by the Engineer.
- (4) Spheres must be constructed from aluminium for direct attachment to OPGW.
- (5) All bolts, nuts and washers shall be A4 grade stainless steel unless otherwise approved by the Engineer.

7. Splicing

7.1 Splice Points

7.1.1 Splice points will be located at the beginning and end of each OPGW drum strung. After completion of sagging and clamping, the surplus OPGW should be coiled and attached temporarily to the tower. Coils should be approximately 1.0 to 1.5 m in diameter. The coils should be clamped onto the tower and solidly bonded to the tower to prevent any arc damage to the OPGW prior to splicing.

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- 7.1.2 The exposed ends of the OPGW should be re-sealed to prevent moisture from entering the fibre units. Electrical tape, RTV silicone, or other means can also be used for this purpose.
- 7.1.3 The OPGW will be attached to the tower using appropriate guide clamps (downlead clamps), spaced every 2 m down the tower. Do not cut off any excess length of the OPGW at this time. To facilitate splicing, the OPGW should extend a minimum of 20 meters beyond the bottom of the tower.
- 7.1.4 The splice enclosure (joint box) will be installed on the structure, typically more than 6 m to 8 m above the ground. In most cases, it will be necessary to attach the excess length of the OPGW on the tower. This will allow the splice box to be removed and lowered to the ground if necessary. This can be accomplished with a simple loop of OPGW permanently attached using appropriate guide clamps above the splice box on the tower.

7.2 Anchoring the Optical Ground Wire in the Splice Box

The following method of anchoring the OPGW must be used when installing loose tube design in a dome type splice box:

- (1) Place a piece of electrical tape on the individual optical units within the OPGW, 360 to 460 mm from the entry bushing of the splice box.
- (2) Working with one optical unit at a time, cut the binder tape at this mark, on the entry bushing side.
- (3) Unwrap the binder tape back to the entry bushing and cut the BINDER TAPE ONLY.
- (4) Cut the yarn at the electrical tape and use the yarn to anchor the optical unit by threading the yarn through the eye-bolt and tying in a series of half-hitches. Make sure that the yarn is tied off in line and to the eye bolt in the proper position from where the individual OPGW conductors enter the splice box.
- (5) Repeat the previous steps for the remaining OPGW conductor(s).
- (6) Tape the optical units together after they have been secured to the eye-bolts. Tape the units (duct tape is recommended) to the top outside radius of the box. This will help support the units and prevent damage of the units at the bushing.
- (7) Tighten the retaining nut so that the bushing is sealed around the pipe.
- (8) Tape the optical units together every 0.6 m.
- (9) Stop taping the optical units 1.8 m from the free end.
- (10) Tape each individual optical unit (s) up to 1.45 m from the free end.
- (11) Remove the yarn and the binder tape from the optical unit(s) along the 1.45 m section towards the free end.

NOTE: The manufacturer of the splice box must supply instructions for installing the loose tube OPGW in their splice box. No matter the type of splice box used, the aramid yarn must be tied off inside the box, to an eye bolt or to another suitable element, to prevent a pull-back tension on the conductor core.

8. Testing

Test requirements stated in this section are as per TE_CNINSTR009.

8.1 Before cable installation

- 8.1.1 Prior to cable installation, each optical fibre is verified using an OTDR.

8.2 Measurements after installation

- 8.2.1 After the cable has been installed, and prior to the splices, each of the cable fibres is verified once again using an OTDR. These new values are compared with those mentioned in 10.1.1 in order to ensure the absence of any problems.
- 8.2.2 Take the basic measurements (i.e. attenuation coefficient, length and position and loss of splice joints) in accordance with SANS 60793-1-40 and ITU-T G.652.D at 1310 nm and 1550 nm.
- 8.2.3 Attenuation tests shall be carried out from both ends, end to end on every fibre after pulling and splicing.

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8.2.4 At handover the average attenuation for the link at 1310 nm shall not be greater than 0.4 dB/km and at 1550 nm the average attenuation shall not be greater than 0.25 dB/km.

8.3 After Splice Measurement

8.3.1 After splicing, each joint is optically verified using the OTDR in order to ensure that the attenuation values are within the required margins.

8.4 Final acceptance test

8.4.1 After installation the complete system shall be tested from end to end. The Client shall be given the opportunity to witness the final acceptance testing in conjunction with the contractor's staff. The Client's presence shall not relieve the Contractor/Supplier of his responsibility for the satisfactory performance of the equipment during site testing and thereafter through to the end of the warranty period.

8.4.2 The following tests for cable systems must be carried out using an OTDR. The basic measurements (i.e. attenuation coefficient, length and position and loss of each splice joint) must be taken in accordance with SANS 60793-1-40.

8.4.3 Set the OTDR length range at least 1.5 times the length of fibre under test to avoid ghosting and echoing. This phenomenon is particularly evident at short lengths (< 1 km).

8.4.4 The correct effective group refractive index as provided by the optical fibre manufacturer must be used. Record this on the data sheet.

8.4.5 Set the helix factor stipulated by the supplier and record it on the data sheet. Record the back-scatter coefficient for each wavelength as supplied by the cable manufacturer.

8.4.6 Record acquisition time settings on the data sheet.

8.4.7 For normal attenuation measurement, the wavelength tolerance shall be within ± 20 nm of the normal central wavelength, for example 1 310 nm or 1 550 nm. Attenuation measurements shall include both wavelengths.

8.4.8 A launch fibre or dead-zone fibre of at least 200 m shall be used and shall be indicated as such on the test results.

8.4.9 All measurements shall be bidirectional.

8.4.10 Store a copy of the final test trace for submission to the Engineer as part of the handover documentation for each fibre.

8.4.11 OTDR traces shall be provided (in PDF and TRC file format) for the complete length of fibre (patch panel enclosure to patch panel enclosure), indicating the distance to joints and the total length of the fibre as well as the loss at each joint. The tests shall be done in both directions at both 1 310 nm and 1 550 nm wavelengths. Trace File Test results shall also be provided on a flash drive or CD. Data shall also be provided on soft copy in both PDF and TRC file format.

NOTE: The best method to determine the loss of a splice is the vertical separation of two best-fit straight lines, usually requiring placement of a pair of cursors on each side of the splice. Most modern instruments support this method as a standard function.

8.4.12 Bidirectional measurements with the same test conditions are required to eliminate the effects of backscatter coefficient differences. The loss calculation is made by averaging the bidirectional readings.

8.4.13 Ensure that the event analysis, event thresholds and event notifier are set.

8.4.14 The following information must appear on each OTDR trace:

- (1) Company name
- (2) Circuit designation
- (3) The designation from which the test is being performed (A)
- (4) Designation of remote end (B)
- (5) Date of test
- (6) Equipment used: Make and model of the OTDR machine, and serial number.
- (7) Number of cores
- (8) Fibre number

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- (9) Index of refraction
- (10) Helix factor; and
- (11) Rayleigh backscatter coefficient.

The Technicians performing the tests shall be trained in the operation of the ODTR equipment being used and in the interpretation of the trace results.

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PART C: SPECIFICATION FOR INSTALLATION OF UNDERGROUND DUCT/TUBE FOR UNDERGROUND OPTICAL FIBRE CABLES

1. Introduction

1.1 Scope

- 1.1.1 This document details the requirements for the installation of ducts for optical fibre communication cables.
- 1.1.2 This includes the installation of the manholes along the route, which are required to facilitate future fibre installation and maintenance.

2. Normative References

SANS 1315	Polypropylene pressure pipes
SANS 4427	Plastics piping systems Polyethylene (PE) pipes and fittings for water supply
SANS 61386-24	Conduit systems for cable management: Particular requirements - Conduit systems buried underground
SANS 1411-7	Materials of insulated electric cables and flexible cords-Part 7: Polyethylene (PE)

3. Definitions

Communication Ducts:	The Pipe Ducting, through which an optical fibre cable is pulled for the establishment of communication links between two points.
Communication Manholes:	The manholes, which are either designed for use within a pavement area or for use within the roadway itself, which are situated along a route and connected by communication Ducts.
Fibre Termination Panel (FTP):	The panel within a substation where the optical fibre cable is terminated into a tray, and made available for optical connection to various optical equipment.
Manhole Ball Markers:	A device which is attached to the inside of a manhole cover, which together with a sensor carried by an operator, is used to pinpoint the exact location of the manhole beneath the surface of the ground.
HDPE:	High Density Polyethylene

4. Specification of Materials

4.1 General

- 4.1.1 Materials include: ducting, manholes and manhole ball markers. The specification of materials to be used is as described in this section.

4.2 Specification of Rigid High-Density Polyethylene (HDPE) Duct for Optical Fibre Cable Communication (40 mm)

- 4.2.1 The duct shall meet the following requirements:
 - (1) The duct shall have a nominal outside diameter of 40 mm.
 - (2) The duct shall have a minimum wall thickness of 3.5 mm.
 - (3) The inner surface of the duct shall have a slippery silicon co-extruded bore for reduction of coefficient of friction.
 - (4) The material of duct shall be virgin high-density polyethylene (HDPE).

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- (5) The high-density polyethylene shall be orange in colour, or another colour if this is specified for a specific project.
- (6) The duct shall have a minimum bending radius of 400 mm.
- (7) The duct shall be supplied in coil lengths ≥ 100 m.
- (8) The duct shall have a pressure rating ≥ 10 bar.
- (9) The duct shall be provided with a pull tape of approximately 800 kg breaking strength.
- (10) The exterior surface of the duct shall be indelibly marked in black with "eThekweni Electricity" at regular one metre intervals in addition to manufacturer's standard marking on the duct.

4.2.2 Each Contractor shall include/provide the following properties of the material of the duct offered:

- (1) Physical properties such as, density, coefficient of linear expansion, thermal conductivity at 20 °C, specific heat, softening point and flammability;
- (2) Mechanical properties such as, tensile strength at yield, elongation at yield, modulus of elasticity, Rockwell hardness and dielectric strength;
- (3) Derating values of temperature against pressure;
- (4) Chemical resistance properties of the duct;
- (5) Codes of Practice regarding handling, storage, cutting and jointing of the duct.

4.2.3 End Cap for Rigid HDPE Duct (40 mm)

- (1) These end caps are for sealing the open ends of the respective pipes already laid in underground but not installed with cable.
- (2) The caps offered shall fit securely on the pipe end.

4.2.4 In – line Compression Coupler for rigid HDPE Duct (40 mm)

- (1) The coupler is for straight jointing of the rigid HDPE duct.
- (2) The coupler shall joint the HDPE duct ends without affecting the inner surface area of the ducts. It shall fit onto the outside of the duct.

4.3 Specification of Flexible Corrugated High-Density Polyethylene (HDPE) Duct for Optical Fibre Cable Communication (50 mm)

4.3.1 A 50 mm outer diameter, flexible, corrugated, black, HDPE duct shall be supplied in accordance to SANS 61386-24.

4.3.2 The duct may be of the Kabelflex type or other equivalent subject to approval.

4.3.3 The walls shall be manufactured with a corrugated construction.

4.3.4 The internal surface of the duct shall be smooth, such that the cables being drawn through it will not be damaged.

4.3.5 The duct shall be for cable systems specifically. Ducts which are manufactured for water and sewage systems shall not be considered.

4.3.6 The duct shall be UV resistant and it shall also be designed for underground burial.

4.3.7 The duct offered shall be of a high tensile and impact strength, being resistant from attack from chemicals likely to be found in average soil conditions.

4.3.8 The duct shall be supplied with a pull string installed within.

4.3.9 Each Contractor shall include/provide the following properties of the material of the duct offered:

- (1) Physical properties such as, density, coefficient of linear expansion, thermal conductivity at 20 °C, specific heat, softening point and flammability;
- (2) Mechanical properties such as, tensile strength at yield, elongation at yield, modulus of elasticity, Rockwell hardness and dielectric strength;

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- (3) Derating values of temperature against pressure;
- (4) Chemical resistance properties of the duct;
- (5) Codes of Practice regarding handling, storage, cutting and jointing of the duct.

4.4 Specification of Communication Modular Manholes

4.4.1 General Requirements

- 4.4.1.1 The design and/or manufacture of the modular manhole shall comply with the relevant SANS or EN Standards. The Standards shall be clearly stated in the bid.
- 4.4.1.2 The materials used to manufacture modular manholes shall conform to SANS 161-2.
- 4.4.1.3 The modular manhole cover shall meet the load rating requirements of SANS 558 (M) Medium Duty.
- 4.4.1.4 The chamber shall conform to SANS 558 medium duty class requirement for use where heavy commercial vehicles have no access.
- 4.4.1.5 The materials used shall be corrosion and UV resistant.
- 4.4.1.6 The chamber, frame and lid, slack brackets, ring beam and epoxy shall have an operating temperature range of 0°C to +50°C.
- 4.4.1.7 The chamber, frame and lid, slack brackets, ring beam and epoxy shall be designed to operate satisfactorily at maximum relative humidity of 95% at 30°C.
- 4.4.1.8 The manhole shall be designed and manufactured for an expected operating lifetime of at least 25 years.
- 4.4.1.9 The modular manhole shall comprise of a lid, frame, chamber and the base. The lid and frame shall form a modular manhole cover.
- 4.4.1.10 The manhole shall have slack management brackets, effective sealing of ducts, as well as knock out duct entries for the required duct entry configuration for any specific point of application.
- 4.4.1.11 The lid shall come standard with a specialised key or combination with a mechanical lock.
- 4.4.1.12 The lid shall be embossed with lettering stating eThekweni Municipality and Logo (above) and eThekweni Electricity (below).
- 4.4.1.13 The logo embossment on the lid shall be at least 10 cm x 10 cm for height and length respectively.
- 4.4.1.14 The chamber shall have covered duct entries of various sizes that can be knocked out when required for use.
- 4.4.1.15 The base shall contain a drainage plug knock-out to prevent water ingress.

4.4.2 Requirements for 600 mm Medium Duty Modular Manhole

- 4.4.2.1 The mass of the modular manhole shall not exceed 50 kg.
- 4.4.2.2 The modular manhole cover shall have a diameter of 700 mm.
- 4.4.2.3 The chamber shall have an effective inner diameter that is 600 mm.
- 4.4.2.4 The chamber shall cater for a minimum depth of 500 mm.
- 4.4.2.5 The chamber shall cater for a minimum of 4 by 110 mm duct entries.
- 4.4.2.6 The chamber shall cater for a minimum of 4 by 50 mm duct entries.
- 4.4.2.7 The chamber shall cater for a minimum of 4 by 40 mm duct entries.

4.4.3 Requirements for 1000 mm Medium Duty Modular Manhole

- 4.4.3.1 The mass of the modular manhole shall not exceed 120 kg.
- 4.4.3.2 The modular manhole cover shall have a diameter of approximately 1100 mm.

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- 4.4.3.3 The chamber shall have an effective inner diameter that is 1000 mm.
- 4.4.3.4 The chamber shall cater for a minimum depth of 750 mm.
- 4.4.3.5 The chamber shall cater for a minimum of 4 by 110 mm duct entries.
- 4.4.3.6 The chamber shall cater for a minimum of 4 by 50 mm duct entries.
- 4.4.3.7 The chamber shall cater for a minimum of 4 by 40 mm duct entries.

4.5 Specification for Communication Concrete Manholes

- 4.5.1 Manholes within roadways are to be of precast concrete or brick, and constructed and installed according to the Engineers requirements and specification.

5. Installation of Communication Duct

5.1 General

- 5.1.1 This includes the installation of the communication ducting and the communication manholes.

5.2 Excavation of Trenches

- 5.2.1 The following procedures outlined are to be followed whenever trenches within road reserve areas are reinstated:
 - (1) Prior to any excavation taking place through hardened surfaces, the proposed trench width shall be marked and saw cut by mechanical means by the Contractor.
 - (2) The minimum depth of any trench shall not be less than 0.6 m on sidewalks and verges, and 1 m in roadways. Any deviation from this requirement must first be authorised by the Engineer.
 - (3) In areas covered with special pavers through which trenching is required, the existing paving shall be carefully removed and stored safely and securely for re-use. This will minimize the need for obtaining new materials to match the existing.
 - (4) In areas where the proposed trench falls within existing works that are being undertaken by any other service provider, it shall be necessary for the responsible Contractor to interact with such service providers for co-ordination and reinstatement purposes.
 - (5) In areas where the proposed trench traverses through established flowerbeds, gardens and grassed sections, it shall be necessary for the Contractor to liaise and interact with the owners or relevant authority, prior to any work commencing.
 - (6) Correct reinstatement by the Contractor of all trench work is necessary to prevent subsidence, but in the case of trenches within hardened surfaces, (i.e. roadways, footpaths, etc.,) special attention must be paid by the Contractor to the correct method of "compacted and layered" backfill.
- 5.2.2 Strict adherence to the procedures given in this Section will ensure the satisfactory reinstatement of the trench.

5.3 Installation of Ducts

5.3.1 Procedures

- (1) The installation of the duct shall be undertaken by the Contractor in accordance with the Layout Drawing.
- (2) The duct drum shall be delivered to site and positioned on a drum trailer with an appropriate braking system. The duct shall then be installed by roll out (refer to **Figure C1**) or by winching (refer to **Figure C2**).
- (3) Support ropes or lines shall be employed for hauling the ducts. However, the support ropes or lines must be of low specific weight and have a high modulus of elasticity.
- (4) The maximum installation force shall be measured, using a calibrated winch-line dynamometer, at the beginning of the duct and maintained throughout the hauling of the duct. The maximum installation force shall be obtained from the manufacturer's data sheet.

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- (5) Should a winch be used, it shall contain a tripping device that would immediately stop the winch should the installation force exceed the maximum installation force. Should a mechanical fuse be used, it shall be designed to break at less than the maximum installation force of the duct. Should a pulley be used, the pulling eyes and cable grips shall not pass over the pulley whilst the duct is under tensile loading.
- (6) When using a winch to haul a duct, the hauling shall begin at low speed and slowly progress to a maximum speed of 75 m/min. The maximum permissible tensile loading of the duct shall, according to the manufacturer's specification, not be exceeded.
- (7) During installation, the Contractor shall ensure that the ducts are clean and that end caps are used.
- (8) The manufacturer's recommendations on bending radii and stresses shall be maintained at all times.
- (9) All ducts shall have their destination sites indelibly tagged on the tube.

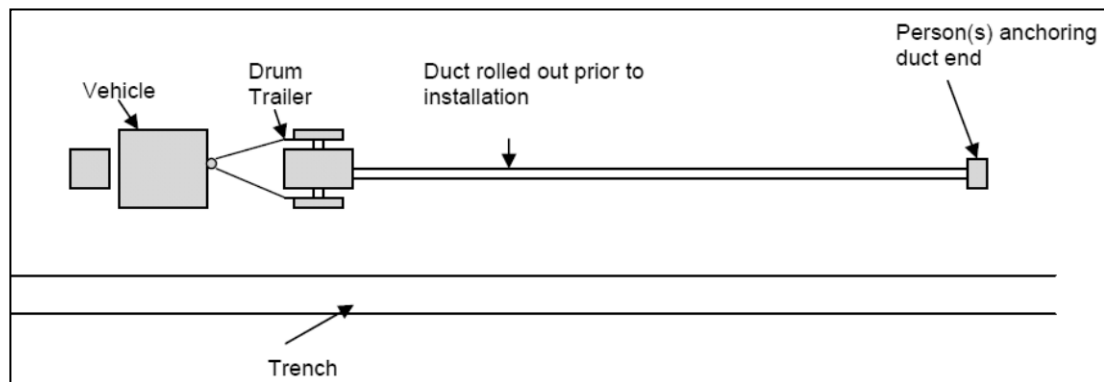


Figure C1: Duct Installation by Roll Out

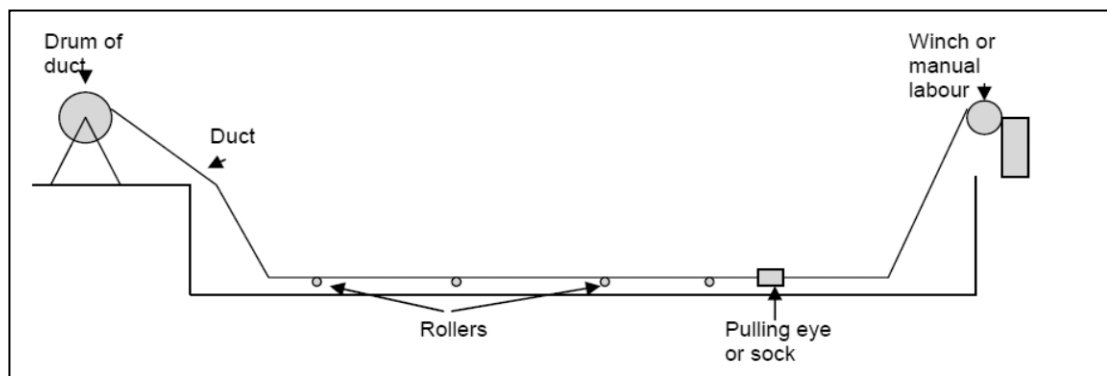


Figure C2: Duct Installation by Winching

6. Backfilling and Reinstatement

6.1 Initial Blinding (Backfilling)

- 6.1.1 Before the duct(s) are laid, suitable blinding material shall be placed onto which the duct will rest without being damaged by any sharp objects.
- 6.1.2 After the duct(s) or cable(s) have been laid, suitable blinding material should be placed around them, and the blinding material should be brought up to a level not exceeding 150 mm.
- 6.1.3 The material should be equally placed on both sides of the duct(s) or cable(s) and each layer should then carefully compacted by making five complete passes over the length of the trench, using a 5 kg hand rammer.

NOTE: Do NOT use a vibrating rammer at this stage as the ducts(s) or cable(s) could easily be damaged.

- 6.1.4 Further layers, each not exceeding 200 mm thickness should now be spread, levelled and compacted by making five complete passes over the layer, still using the hand rammer, until the duct or cable is covered by well compacted blinding material to a height of 300 mm above the top of the duct(s) or cable(s).

NOTE: If ducts are laid in a cluster the blinding material must be brought up in layers of 150 mm until a cover of

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300 mm above the top duct is obtained.

6.2 Compacting the Trench Bottom

- 6.2.1 Compaction of suitable bedding material can be achieved by making two passes over the whole trench bed, preferably using a power vibrating rammer or a 5 kg hand rammer as an alternative.
- 6.2.2 The cable or duct can then be laid on the prepared bed.

6.3 Suitable Backfill Material

- 6.3.1 General backfill can be carried out by using the material excavated from the trench, provided that:
 - (1) It is easily workable and compactable
 - (2) It is free from organic material (roots, grass, etc...) rubbish, clay lumps and aggregates larger than 50 mm stones in diameter.
 - (3) The material is suitable, is not water saturated or too dry. Should the material be too dry, it will be moistened prior to placing and compacting.
- 6.3.2 In the immediate vicinity of the duct or cable both below and up to a height of 300 mm above, stone-free material must be used (beach and river sand are not suitable due to their high thermal resistivity).
- 6.3.3 Lay concrete slabs (0.5m x 0.5m 50mm thick) at a depth of 300 mm, and lay a marker tape on top of the concrete slab.
- 6.3.4 If the site materials cannot meet these requirements suitable material must be imported.
- 6.3.5 A "Dynamic Core Penetrometer" (DCP) is used for the following reasons:
 - (1) To ensure that the required compaction of the trench has been achieved, tests must be carried out by the Contractor at various levels.
 - (2) The tests are carried out using a DCP which consists of a metal rod with a cone-shaped end and an anvil onto which a fixed weight falls through a set distance.
 - (3) The following test results are deemed to be acceptable, as minimum requirements for compaction of trench backfill using DCP test method:
 - (a) In roadways – 5 blows per 100 mm penetration.
 - (b) In footpaths, driveways and medians – 3 blows per 100 mm penetration.
 - (c) In verges – 2 blows per 100 mm penetration.

NOTE: The greater the number of blows required to penetrate the 100 mm the better the soil compaction at the point of the test.

- 6.3.6 Initial testing using DCP:
 - (1) Tests carried out at this stage, i.e. 300 mm above duct(s) or cable(s), using DCP, would be considered satisfactory if at least two blows are required to penetrate 100 mm.

NOTE: Tests must be carried out to one side of the duct or cable, and not immediately above.

6.4 Final Backfilling

- 6.4.1 From the level of 300 mm above the duct or cable to the top of the trench, backfilling should proceed using suitable backfill material, with layer thickness now being increased to 200 mm (before compaction).
- 6.4.2 Each layer should be thoroughly compacted by making four complete passes over the whole trench area with a power vibrating rammer.
- 6.4.3 All driveways shall be reinstated using an approximate ratio of 20:1 of backfill to cement. This mixture shall be

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applied to the top backfill layer between 75 mm – 100 mm and the cement shall have strength of 10 MPa. No driveway shall be left uncapped for any period of time.

6.5 Trenches in Verge Areas

- 6.5.1 The final 75 mm -100 mm of trench backfill shall comprise of an organic/topsoil type material, placed and levelled off flush. No humps and bumps shall be permitted.
- 6.5.2 All loose stones and other obstructions shall be removed to the spoil site.
- 6.5.3 A suitable ground cover shall be established over the trench width approved by the Engineer.

6.6 Responsibility for Maintenance of the Trench and Final Reinstatement

- 6.6.1 The responsibility for the maintenance of the trench in the period between the initial backfilling and final reinstatement is that of the Contractor.

6.7 Surplus Material

- 6.7.1 All surplus material from trench excavation must be removed by the Contractor to a designated spoil site. Should excavated material remain on site for backfill purposes, it shall be adequately barricaded.
- 6.7.2 Should excavated material end up in the Municipality's storm water infrastructure, it will be removed at the responsible contractor's expense.

6.8 Service-Related Structures

- 6.8.1 All structures such as manholes, chambers, earth retainers and connecting junction boxes shall be constructed to a design approved by the Engineer.
- 6.8.2 All exposed vertical surfaces above ground shall be either of a face brick or concrete of shutter finish.
- 6.8.3 Where earth retainers are used, such as dry stacking, interlocking retaining systems, example "loffelstein" blocks or equivalent, these shall be erected to the manufacturer's guidelines and specifications.
- 6.8.4 The finish level on manhole covers shall be true horizontal with the surrounding levels modified to tie in.

6.9 Laying of Communication Ducts within Electricity Substation Yards

- 6.9.1 Two rigid HDPE ducts are to be laid unless otherwise specified by the Engineer.
- 6.9.2 Where fibre communication ducts are to be installed into trenches (i.e. control cable trenches) laid at the same depth as the supply and control cables; there should be at least 50 mm spacing between the ducts and any power supply cables.
- 6.9.3 Where trenching is used specifically for the installation of communication ducts, the two rigid HPDE ducts must be buried not less than 800 mm deep for the entire route. No mechanical means of trenching is allowed.
- 6.9.4 Ducts installed within substations yards must be laid within the substation cable trenches, where practical. Where large bending radii are possible, the HDPE ducting/ tubing may also be installed from the tower/gantry manhole position into the substation building. If the required bends into the substation building are too tight for the HDPE duct, or where the route terminates onto a Fibre Termination Panel (FTP), 50 mm diameter flexible corrugated ducting must be used for the last section of the link.
- 6.9.5 The Engineer shall approve the water-tight pipe couplers between sections of communication ducting and these must be used to prevent ingress of moisture and mud. Connections between HDPE duct and flexible corrugated duct must also be water tight.

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6.10 Installation of Communication Manholes

- 6.10.1 Communication manholes are to be placed at 200 m intervals or less. Manholes are also to be installed where the duct deviates beyond 30 degrees and at the terminal tower or gantry where fibre cable to OPGW transition points are located.
- 6.10.2 Communication ducts must be well sealed at entry/exit points of the manhole. All ducting ends within the manhole must be sealed with the proper supplier's endcaps.

6.11 Joining Between Duct Cable and Overhead Optical Ground Wire (OPGW).

- 6.11.1 Approved dome joint boxes must be mounted onto the top of a vertically installed 1.8m long, 63 mm diameter stainless-steel pipe buried 600 mm into the ground. The pipe must be secured to the inside of the tower leg/ just off the gantry or pylon leg, using an approved stainless-steel bracket.
- 6.11.2 Sufficient OPGW slack is to be coiled and secured above the anti-climbing barrier on the OPGW side of the dome joint prior to splicing, this will enable the dome joint to be worked on at ground level, at the base of the tower/ gantry.
- 6.11.3 Where rigid HDPE duct is run to the dome joint position, a length of the flexible HDPE duct must be joined to the rigid HDPE duct from the tower base manhole, and inserted into the base of the stainless-steel pipe. Joints must be taped with self-amalgamating rubber tape to prevent the ingress of moisture and sand. Approximately 5 m cable slack must be coiled in the manhole.

7. Handover Requirements and Procedures

- 7.1.1 The following paperwork must be completed and handed over to the Engineer before handover and before payment may be authorized.

7.2 Documentation of Route

- 7.2.1 The entire ducting route, all manholes and all joint positions must be properly surveyed and co-ordinates marked on the associated drawing plans and forwarded to the Engineers Office for capture onto the drawing office database – to facilitate future fault location.
- 7.2.2 A copy of the final 'as-built' drawing must be forwarded to the Engineer/ Supervisor overseeing the installation.

7.3 Completion of Communication Ducting Handover Form

- 7.3.1 The contractor/ cable layer is to ensure and confirm that the ducts have been laid according to the specifications and any additional requirements stipulated by the Engineer.
- 7.3.2 The "Communication Duct Handover Form" detailed in **Annexure A** shall be completed and returned to the appointed Clerk of Works/ Supervisor after completion and at handover of the work.

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PART D: SPECIFICATION FOR THE INSTALLATION OF UNDERGROUND OPTICAL FIBRE DUCT CABLE INTO UNDERGROUND CABLE DUCTS/TUBE

1. Introduction

1.1 Scope

- 1.1.1 The purpose of this document is to detail the requirements for the pulling of optical fibre duct cable into existing duct, and the handing over of the completed link.

2. Normative and TE References

IEC /SANS 60793-1-40	Optical fibres– Part 1-Section 40: Measurement methods and test procedures – Attenuation
TE_CNINSTR019	Technical Instruction- 19-inch FOC Termination and Tray Installation in FTP
TE_CNINSTR008	Technical Instruction- Comms Networks Labelling
TE_CNINSTR009	Technical Instruction- Fibre Optic Cable Testing

3. Definitions

Communication Ducts:	The duct tubing, as specified by the Engineer, through which optical fibre cable is pulled for the establishment of communication links between two points.
Communication Manholes:	The manholes, which are either designed for use within a pavement area or for use at tower or gantry or substation yard, which are situated along a route and connected by communication ducts.
Fibre Termination Panel (FTP):	The panel within a substation where the optical fibre cable is terminated into a tray.
Dome Joint box:	An approved sealed enclosure used to secure and accommodate splices made between two sections of fibre. Joint box to be positioned in an approved location on the gantry or tower.
HDPE	High Density Polyethylene

4. Installation of Optical Fibre Duct Cable

4.1 General

- 4.1.1 The pulling of cable proceeds after the installation of the communication ducts/ tubes. This process may begin only once it has been confirmed that the communication tubing, including installation of communication manholes, and documentation, has been completed and handed over.

4.2 Attenuation Tests Prior to Installation

- 4.2.1 Attenuation tests shall be carried out on every fibre of the cable while still on the drum to confirm that the fibre drums are in good order after delivery and have been received by the contractor/ installer, prior to pulling.
- 4.2.2 Cables with an average attenuation in any single mode fibre at 1550 nm above 0.25 dB/km, or above 0.4 dB/km at 1310 nm, shall not be accepted.
- 4.2.3 The form used to confirm the results of the attenuation test is provided in **Annexure B**.

4.3 Installation of Optical Fibre Cable by Winching or Manual Labour

- 4.3.1 The optical fibre cable drum shall be delivered to site and positioned on a drum trailer with an appropriate braking

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system (Refer to **Figure C1**).

NOTE: Ensure that the manufacturer's specification document is delivered together with the cable drum.

- 4.3.2 Hauling ropes or lines shall be employed for winching the optical fibre cable. However, the ropes or lines must be of low specific weight and have a high modulus of elasticity. Steel wires or similar metallic support lines shall not be used in PE or PVC ducts.
- 4.3.3 The optical fibre cable connection to the hauling rope or lines shall be made using the factory fitted pulling eyes or by cable grips.
- 4.3.4 The hauling rope at the end of the optical fibre cable shall be connected to a twist compensation device to reduce the twisting during the winching of the cable.
- 4.3.5 The optical fibre cable strength and haul length shall be considered when being hauled through the duct. Consult the manufacturer's specification for these measurements.
- 4.3.6 The maximum installation force shall be measured using a calibrated winch- line dynamometer, at the beginning of the optical fibre cable and shall be maintained throughout the winching of the cable. Consult the manufacturer's specification for the maximum installation force.
- 4.3.7 The winching shall begin at low speed and slowly progress to a maximum speed of 75 m/min. The maximum permissible tensile loading of the optical fibre cable shall not be exceeded. Consult the manufacturer's specification for the maximum permissible tensile loading.

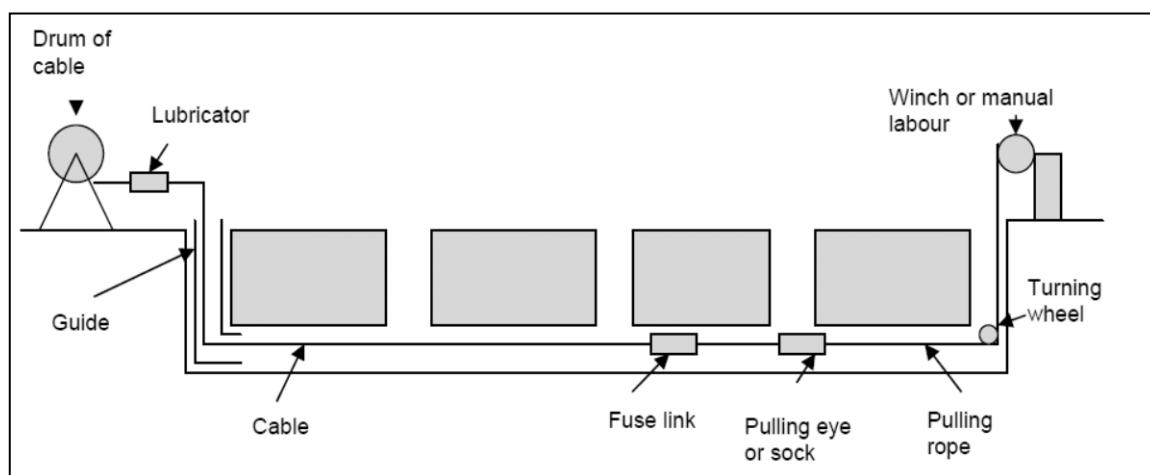


Figure C1: Winching of Optical Fibre Cable

- 4.3.8 "Free guiding tools" shall be utilized at curvatures on the cables route and at duct entrances to ensure that the minimum bending radii recommended for the duct is maintained.
- 4.3.9 Utmost care must be taken to guard against over- bending and over-tensioning of the cable in the process of pulling.
- 4.3.10 It should be noted that the drawer wires/fibre supplied in the communication tubing must not be used to pull the fibre cable. Instead a haul rope must be used to pull the actual cable.
- 4.3.11 The cables must be hand pulled, mechanical pulling devices may only be used with explicit approval and under direct supervision of the Engineer or his representative.
- 4.3.12 Every care must be taken to prevent damage to existing cables / services whilst installing new cables.
- 4.3.13 The cable must be manhandled at every manhole along the way to prevent unnecessary drag on existing services.
- 4.3.14 Cable lubrication may be necessary when installing cables in occupied ducts, provided this has no detrimental effect on the cable or pipes/ ducts.
- 4.3.15 The cable should be pulled with a continuous rhythmic motion, sharp jerks must be avoided.
- 4.3.16 At least 5 m of slack must be looped and retained within each communication manhole.

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4.3.17 At least 5 m of slack should be looped at the base of the tower/ gantry leg manhole where duct optical fibre cables are to be join onto Optical Ground Wire (OPGW) on the tower or gantry.

4.3.18 Self-expanding polystyrene type foam shall be injected into the communication duct openings, after the cable has been pulled, to seal the ends of the ducts and to stop the ingress of sand, rodents, etc.

4.4 Splicing

4.4.1 Splicing must only be carried out using equipment that has been approved by the Engineer.

4.4.2 The splicing shall be performed by a team of at least two members.

4.4.3 In addition to the safety requirements associated with work on a heavy-duty duct optical fibre cable to OPGW dome joint installation, the following competencies shall be in place:

- (1) Team member 1: Electronic technician with three years' experience in OPGW jointing: portfolio to be made available on request.
- (2) Team member 2: Trade tested artisan (Electrical/ Mechanical/ Civil) recognised by the Department of Labour with three years' experience in OPGW jointing – portfolio to be made available on request.

4.4.4 For both team members, experience on OPGW dome joint installation and optical fibre termination is essential.

4.4.5 All optical fibre training/certification shall be approved by a SETA accredited service provider or the Fibre Optic Association. Certified copies of the qualification shall be made available on request.

4.5 Jointing and Splicing Between Sections of Underground Optical Fibre Duct Cable.

4.5.1 Fibres must be fusion spliced, and must have a loss equal or less than 0.1 dB.

4.5.2 An approved optical fibre dome joint box must be used to contain the splices between the optical fibre cable and the OPGW. The dome joint box must be installed on the tower or gantry.

4.5.3 Jointing within the box must be carried out strictly according to the supplier's specification. Joint boxes must be suitably sealed to prevent ingress of moisture, and must therefore be waterproof.

4.5.4 At least 5 m of slack from each end should be coiled neatly into the manhole adjacent to the tower/gantry.

4.5.5 Jointing and Splicing between sections of underground optical fibre duct cable and Overhead Optical Ground Wire (OPGW)

4.5.6 Joints between OPGW and duct optical fibre cable sections must be housed within a stainless-steel dome joint box approved by the Engineer

4.5.7 The approved stainless-steel joint box must be mounted onto the top of a vertically installed, 1.8m long, 63 mm diameter stainless-steel pipe buried 600 mm into the ground. The pipe must be secured to the inside of the tower leg/ just off the gantry leg or pylon using the approved stainless-steel bracket approved by the Engineer.

4.5.8 Flexible corrugated HDPE ducting for the duct fibre cable must be inserted into the base of the stainless-steel pipe. Where the communication ducting is HDPE, the flexible and rigid ducting/ tubing must be water tight and taped with self-amalgamating rubber tape to prevent the ingress of moisture and sand.

4.5.9 The top of the pipe must be sealed with self-expanding polystyrene type foam ('Sista') to prevent ingress of water.

4.5.10 Jointing within the box must be carried out strictly according to the supplier's specification. The correct cable clamping ferrules and half shells at the base of the joint must be used. Joint boxes must be suitably sealed to prevent ingress of moisture.

4.5.11 Termination of Underground Optical Fibre Duct Cable into Fibre Termination Panel (FTP):

- (1) Both the optical fibre duct cable and the communication tubing in which the cable runs must be properly terminated at the FTP and into a 19" rack in a designated location at either end of the link (Refer to Technical Instruction TE_CNINSTR019).
- (2) The individually coloured fibre cores must be numbered according to international numbering convention as detailed in **PART A**.

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- (3) The optical fibres of the fibre transmission link must be fusion spliced to the pigtails in the 19-inch tray in the Fibre Termination Panel (FTP) at the termination point, using a core aligning machine. The attenuation loss across splices must not be greater than 0.1 dB.
- (4) The Fibre Termination Panel (FTP) and tray must be labelled as per Technical Instruction TE_CNINSTR008.

5. Handover and Procedures

5.1 General

- 5.1.1 Handover occurs once the contractor/ installer of a link has completed the installation, when all splices have been completed and when the contractor has fully and successfully tested and proved the fibre link, from termination point to termination point. A termination point is at the tray within the Fibre Termination Panel (FTP) at a substation, unless otherwise specified by the Engineer.

5.2 Test Equipment

- 5.2.1 The test instrument used for the testing of fibre on transmission links must be an Optical Time Domain Reflectometer (OTDR), approved by the Engineer.

5.3 Red Light-Source Test

- 5.3.1 A red-light source must be used to check for basic continuity and to ensure that there are no cross-overs between termination points.

5.4 Attenuation Tests

- 5.4.1 Carry out the following tests for cable systems with joints in the total length (excluding joints in fibre distribution units) using an OTDR. Take the basic measurements (i.e. attenuation coefficient, length and position and loss of splice joints) in accordance with SANS 60793-1-40 or ITU-T G.652.D at 1310 nm and 1550 nm.
- 5.4.2 Attenuation tests shall be carried out from both ends, end to end on every fibre after pulling and splicing.
- 5.4.3 At handover the average attenuation for the link at 1310 nm shall not be greater than 0.4 dB/km and at 1550 nm the average attenuation shall not be greater than 0.25 dB/km.

5.5 Optical Time Domain Reflectometer Tests

- 5.5.1 Test requirements stated in this section are as per TE_CNINSTR009.
- 5.5.2 Each core must be tested using the approved OTDR from each end of the link, at 1550 nm and at 1310 nm. The report shall also include labels describing the physical location of any events of the route.
- 5.5.3 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 (< 1 km).
- 5.5.4 Use the correct effective group refractive index as provided by the optical fibre manufacturer. Indicate this on the splice summary table.
- 5.5.5 Set the helix factor stipulated by the supplier and record it on the splice summary table.
- 5.5.6 Indicate on the splice summary table the back-scatter coefficient for each wavelength as supplied by the cable manufacturer.
- 5.5.7 Indicate acquisition time settings on the splice summary table.
- 5.5.8 Ensure that the event analysis, event thresholds and event recorder are set.
- 5.5.9 Adhere to the OTDR maximum pulse widths as given in the **Table C1**.

Table C1: OTDR maximum pulse widths

Range	Maximum pulse width
(km)	(ns)
< 2	100
> 2 and < 20	500
>20 and < 50	1 000
> 50	2 500

5.5.10 Insert the following information on each OTDR trace:

- (1) Date;
- (2) Optical fibre cable circuit description;
- (3) Fibre number;
- (4) The end from which the test is being performed;
- (5) Index of refraction;
- (6) Helix factor; and
- (7) Rayleigh backscatter coefficient.

5.5.11 OTDR traces shall be provided (in PDF and TRC file format) for the complete length of fibre (patch panel enclosure to patch panel enclosure), indicating the distance to joints and the total length of the fibre as well as the loss at each joint. The tests shall be done in both directions at both 1 310 nm and 1 550 nm windows. Test results shall also be provided on a Compact disc or Flash disc.

5.6 Handover Documentation

5.6.1 The documentation required at handover and prior to payment are as follows:

- (1) The completed "Completion Form for Optical Fibre Links" as detailed in **Annexure C**.
- (2) Copies of the results of the OTDR tests on CD (in PDF and TRC file format) and hard copy.
- (3) Details of the helix factor, the index of refraction, and the Rayleigh backscatter factor of the fibre cable used.

5.6.2 Copies of this documentation shall be provided to both the Engineer and Supervisor after completion and at handover of the work.

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TECHNICAL SCHEDULES A AND B FOR: OPGW

Schedule A: Purchaser's specific requirements

Schedule B: Particulars of Tender Offer

Item	Description	UNITS	Schedule A Particular Requirements	Schedule B Tender Offer
1.0	GENERAL			
1.1	Pollution level, if other than heavy		Heavy	
1.2	Maximum temperature, if other than 50 °C	°C	50	
1.3	Minimum temperature, if other than -5 °C	°C	-5	
1.4	Maximum wind speed, if other than 36 m/s	m/s	36	
1.5	Route altitude, if other than 2 000 m	m	1000	
1.6	Solar Radiation Level	W/m ²	1100	
1.7	Standard to which conductor complies		SANS/ IEC 61089	
2.0	Conductor Type 1		'OAK Equivalent'	
2.1	Name of manufacturer		xxxxxxxxxx	
2.2	Place of manufacture		xxxxxxxxxx	
2.3	Manufacturer's reference number		xxxxxxxxxx	
2.4	Nominal aluminium area	mm ²	xxxxxxxxxx	
2.5	Stranding of conductors	mm	Multi-layered	
2.6	Actual cross-sectional area	mm ²	xxxxxxxxxx	
2.7	Approximate overall diameter	mm	14.6	
2.8	Mass of cable	kg/m	xxxxxxxxxx	
2.9	Maximum d.c. resistance at 20°C per km	Ω/km	0.2769	
2.10	Ultimate tensile strength, UTS- minimum	N	35 000	
2.11	Rated tensile strength (RTS)		xxxxxxxxxx	
2.12	Initial modulus of elasticity	N/mm ²	59 000	
2.13	Final modulus of elasticity			
2.14	Temperature Coefficient of linear expansion	/°C	23 x 10 ⁻⁶	
2.15	Temperature Coefficient of Resistance	/°C	0.0036	
2.16	Direction of lay of outer layer		right-handed	
2.17	Maximum working tension at -5°C and 700Pa wind pressure (40% of UTS)	N	13 320	
2.18	Maximum Tension at 15°C in still air (20% of UTS)	N	6 600	
2.19	Short-circuit rating for initial/final temperature of 40/400°C	kA ² .s	263.7	
2.20	Continuous current-carrying capability A	A	xxxxxxxxxx	
2.21	OPGW 1 s current rating kA		xxxxxxxxxx	
2.22	Number of fibre cores		24/ 48	
2.23	Conductor material		All Aluminium Alloy	
2.24	Grease conductor in accordance with SANS 61089 and		Yes- case 4	

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TECHNICAL SCHEDULES A AND B FOR: OPGW

Schedule A: Purchaser's specific requirements

Schedule B: Particulars of Tender Offer

Item	Description	UNITS	Schedule A Particular Requirements	Schedule B Tender Offer
	case?			
2.25	Complete details of cable construction, including measures to minimize hydrogen absorption and water ingress.		xxxxxxxxxx	
2.26	Is a sample required?		Within one week of request	
2.27	Length of sample, if not 1 m	m	2	
2.28	Maximum drum length of OPGW		xxxxxxxxxx	
2.29	Mass of drum including max. length of OPGW cable		xxxxxxxxxx	
2.30	Is documentation required?		Yes	
2.31	Specify class of cable 0, 1, 2 or 3		1	
3.0	Conductor Type 2		'ELM Equivalent'	
3.1	Name of manufacturer		xxxxxxxxxx	
3.2	Place of manufacture		xxxxxxxxxx	
3.3	Manufacturer's reference number		xxxxxxxxxx	
3.4	Nominal aluminium area- minimum	mm ²	175	
3.5	Stranding of conductor	mm	Multi-layered	
3.6	Actual cross-sectional area- minimum	mm ²	211.0	
3.7	Approximate overall diameter	mm	18.8	
3.8	Mass of cable	kg/m	580	
3.9	Maximum d.c. resistance at 20°C per km	Ω/km	0.1568	
3.10	Ultimate tensile strength, UTS	N	59 100	
3.11	Rated tensile strength (RTS)	N	xxxxxxxxxx	
3.12	Initial modulus of elasticity	N/mm ²	59 000	
3.13	Final modulus of elasticity	N/mm ²	59 650	
3.14	Temperature Coefficient of linear expansion	/°C	23 x 10 ⁻⁶	
3.15	Temperature Coefficient of Resistance	/°C	0.0036	
3.16	Direction of lay of outer layer		right-handed	
3.17	Maximum working tension at -5°C and 700Pa wind pressure (40% of UTS)	N	23 640	
3.18	Maximum Tension at 15°C in still air (20% of UTS)	N	11 820	
3.19	Short-circuit rating for initial/final temperature of 40/400°C	kA ² .s	830.4	

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TECHNICAL SCHEDULES A AND B FOR: OPGW

Schedule A: Purchaser's specific requirements

Schedule B: Particulars of Tender Offer

Item	Description	UNITS	Schedule A Particular Requirements	Schedule B Tender Offer
3.20	Continuous current-carrying capability A	A	xxxxxxxxxx	
3.21	OPGW 1 s current rating kA		xxxxxxxxxx	
3.22	Number of fibre cores		24/ 48/ 96	
3.23	Conductor material		All Aluminium Alloy	
3.24	Grease conductor in accordance with SANS 61089 and case?		Yes- case 4	
3.25	Complete details of cable construction, including measures to minimize hydrogen absorption and water ingress.		xxxxxxxxxx	
3.26	Is a sample required?		Within one week of request	
3.27	Length of sample, if not 1 m	m	2	
3.28	Maximum drum length of OPGW		xxxxxxxxxx	
3.29	Mass of drum including max. length of OPGW cable		xxxxxxxxxx	
4.0	Fibre Testing:			
4.1	Equipment: Calibrated, Optical Time Domain Reflectometer (OTDR)		Approved by the Engineer	
4.2	Maximum average attenuation per fibre on a drum at:			
	(1) 1310nm	dB/km	0.4	
	(2) 1550nm	dB/km	0.25	
4.3	Maximum variation in attenuation on consecutive 1km pieces of cable at 1310 nm and 1550 nm.	dB/km	0.1	
4.4	Maximum step increase (point defect or splice) at 1310 nm and 1550 nm.	dB	0.1	
4.5	Average splice loss at 1310 nm and 1550 nm.	dB	0.075	
4.6	Cable OTDR test on all fibres to be done on each drum prior to factory dispatch- Test records to be supplied.	-	Yes	

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TECHNICAL SCHEDULES A AND B FOR: HEAVY DUTY DUCT CABLE

Schedule A: Purchaser's specific requirements

Schedule B: Particulars of Tender Offer

Item	Description	UNITS	Schedule A Particular Requirements	Schedule B Tender Offer
1.0	GENERAL			
1.1	Pollution level, if other than heavy		Heavy	
1.2	Maximum temperature capacity, if other than 50 °C	°C	70	
1.3	Minimum temperature capacity, if other than -5 °C	°C	-5	
1.4	Route altitude	m	Sea level - 800 m	
1.5	Colour of Outer Cable Sheath/Jacket		Orange	
1.6	Type of Outer Cable Sheath/Jacket		HDPE	
1.7	Tube Colour Code according to IEC 60304 – refer to table in Annexure F .		See Annexure F	
1.8	Filler (where applicable)/ Loose buffer tubes without fibres		Yellow	
1.9	Rodent protection and traction-resistant peripheral strength member		xxxxxxxxxx	
1.10	Dry water-blocking materials used		xxxxxxxxxx	
1.11	Maximum Number of fibre cores per tube		12	
1.12	Peripheral Strength member		xxxxxxxxxx	
1.13	Central Strength Member Material		xxxxxxxxxx	
2.0	Heavy-Duty Loose Tube All Dielectric Duct Cable-Type 24	No. of Fibres	24/ 48/ 96	
2.1	Name of manufacturer		xxxxxxxxxx	
2.2	Place of manufacture		xxxxxxxxxx	
2.3	Manufacturer's reference number		xxxxxxxxxx	
2.4	Number of elements		xxxxxxxxxx	
2.5	Approximate overall diameter	mm		
2.6	Mass of cable (nominal)	kg/m	xxxxxxxxxx	
2.7	Maximum Tensile Load IEC 60794-1-E1	N	xxxxxxxxxx	
2.8	Number of Loose Tubes		24 fibre: 2 or 4; 48 fibre: 4 or 8 96 fibre: 8	
2.9	Number of fibre cores per tube		24 fibre: 12 or 6; 48 fibre: 14 or 6 96 fibre: 12	
2.10	Maximum Installation Pulling tension	N	xxxxxxxxxx	
2.11	Minimum Bending Radius IEC 60794-1-11	mm	xxxxxxxxxx	
2.12	Maximum Drum Length	m	xxxxxxxxxx	
2.13	Mass Drum including Maximum Cable Length	kg	xxxxxxxxxx	
2.14	Mass Drum including Maximum Cable Length	kg	xxxxxxxxxx	

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TECHNICAL SCHEDULES A AND B FOR: HEAVY DUTY DUCT CABLE

Schedule A: Purchaser's specific requirements

Schedule B: Particulars of Tender Offer

Item	Description	UNITS	Schedule A Particular Requirements	Schedule B Tender Offer
3.0	Fibre Testing:			
3.1	Equipment: Calibrated, Optical Time Domain Reflectometer (OTDR)		Approved by the Engineer	
3.2	Maximum average attenuation per fibre on a drum at:			
	(1) 1310nm	dB/km	0.4	
	(2) 1550nm	dB/km	0.25	
3.3	Maximum variation in attenuation on consecutive 1km pieces of cable at 1310 nm and 1550 nm.	dB/km	0.1	
3.4	Maximum step increase (point defect or splice) at 1310 nm and 1550 nm.	dB	0.1	
3.5	Average splice loss at 1310 nm and 1550 nm.	dB	0.075	
3.6	Cable OTDR test on all fibres to be done on each drum prior to factory dispatch- Test records to be supplied.	-	Yes	
4.0	Cable Type Testing:			
4.1	Impact resistance IEC 60794-1-E4 (25mm anvil / 10 blows)	Nm blows	- No attenuation increase	
4.2	Crush resistance via 100mm plates IEC 60794-1-E3, 20 N/mm		- No attenuation increase	
4.3	Water penetration (3m cable, 1m head of water) IEC 60794-1-5B		- No leakage	
4.4	Drip test (300mm sample of loose tube @80°C) IEC 60794-1-14		Yes	
4.5	Bending resistance IEC 60794-1-E11 Procedure 1		- No attenuation increase	

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TECHNICAL SCHEDULES A AND B FOR: SINGLE MODE FIBRE

Schedule A: Purchaser's specific requirements

Schedule B: Particulars of Tender Offer

Item	Description	UNITS	Schedule A Specific Requirements	Schedule B Tender Offer
1.0	Optical Fibre Physical Characteristics			
1.1	Fibre Type, Dispersion- Unshifted to ITU-T		G.652.D	
1.2	Fibre Core size (Mode Field Diameter 1310 nm)	µm	9.2± 0.4	
1.3	Cladding Diameter	µm	125 ± 0.7	
1.4	Core-Clad Concentricity	µm	≤ 0.6	
1.5	Coating Diameter (Coloured)	µm	254 ± 7	
1.6	Coating-Cladding Concentricity	µm	12	
1.7	Clad Non-Circularity	%	≤ 1	
1.7	Fibre Core Colour Code according to ANSI/TIA/EIA-598 and IEC 60304– refer to table in Annexure E .		See Annexure E	
2.0	Optical Fibre Mechanical Characteristics			
2.1	Proof test	GPa	≥ 0.69	
2.2	Coating Strip Force	N	1.3 - 8.9	
2.3	Fibre Curl	m	≥ 4	
2.4	Dynamic Fatigue Parameter	nd	≥ 18	
2.5	Macro-bend 100 turns @ 50mm mandrel -1550 nm	dB	≤ 0.05	
2.6	Macro-bend 1 turn @ 32mm mandrel - 1550 nm	dB	≤ 0.05	
3.0	Optical Fibre Environmental Characteristics			
3.1	Temperature Dependence -60°C to +85°C	dB	≤ 0.05	
3.2	Temperature Humidity Cycling -10°C to 85°C up to 95% Relative Humidity	dB	≤ 0.05	
3.3	Water Immersion, 23 + 2°C	dB	≤ 0.05	
3.4	Heat Aging, 85 + 2°C	dB	≤ 0.05	
4.0	Optical Fibre Characteristics, Wavelength Specific			
4.1	Attenuation loss for Loose Tube Cable			
	At 1310 nm	dB/km	≤ 0.40	
	At 1550 nm	dB/km	≤ 0.25	
4.2	Mode Field Diameter			
	(i) At 1310 nm	µm	9.2 ± 0.4	
	(ii) At 1550 nm	µm	10.4 ± 0.6	
4.3	Group Refractive Index			
	(i) At 1310 nm		1.467	
	(ii) At 1550 nm		1.468	
4.4	Point Defects	dB	0.10	
4.5	Cut-off Wavelength	nm	1260	
4.6	Zero Dispersion Wavelength	nm	1300 - 1324	
4.7	Zero Dispersion Slope	ps / km.nm ²	0.092	
4.8	Polarization Mode Dispersion (PMD)	ps / √km	≤ 0.2	

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ANNEXURE A: COMMUNICATION DUCT SYSTEM HANDOVER FORM

Preamble

This checklist is to be completed and signed in sequence by the Contractor/Installer and the Employer's Agent, once the installation of the fibre communication duct and associated items has been completed.

LINK DESCRIPTION:			
Contract No./ Order No.:			
End A:		End B:	
Total Length of Route:		No. of Manholes:	
Average Distance Between Manholes:		Maximum Distance Between Manholes:	

Item	Description	Complies (Y/N or N/A)	Remarks
1.	Manholes are positioned at the tower or gantry – if applicable.		
2.	Manholes are positioned at bends greater than 30° in the route to facilitate the pulling of the fibre cable.		
3.	The ducting used has been approved by the Engineer.		
4.	All ducting into the manhole has been sealed with proper supplier's end- caps.		
5.	An 'as-built' diagram of the entire duct route, showing the surveyed position of all manholes, and the manholes which accommodate joints have been submitted to the Engineer.		
6.	Joints between rigid and flexible ducts, are water tight.		
7.	Flexible duct for the dome joint end has been capped and sealed against water ingress.		

Completed By:

	Contractor/Installer	Employer's Agent
Name:		
Signature:		
Company:		
Date:		

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ANNEXURE C: COMPLETION FORM FOR OPTICAL FIBRE LINKS

Note: This form is a template to illustrate the requirements. For actual implementation, a new form shall be compiled in Word or Excel.

Preamble

This checklist is to be completed and signed in sequence by the Contractor/Installer and the Employer's Agent, as and when the work for aspects of a particular fibre transmission link are completed. The same sheet is to be used for aerial and underground systems. This form shall be filled-in per link, per circuit (if aerial and located on a transmission line).

LINK DESCRIPTION:			
Contract No./ Order No.:			
End A:		End B:	
Length of Link:		Make & Model of Fusion Splicer Used:	
No. of Joint Boxes:		Make & Model of OTDR Used:	
No. of Fibres:		Permitted Link Attenuation Loss 1310 nm:	
No. of Tubes:		Permitted Link Attenuation Loss 1550 nm:	

Item	Description	Date	Signature
1.	OPGW: Considerations during Stringing of the Conductor at Towers where Splice Enclosures are to be Erected:		
a.	The joints/ splices were installed at accessible towers and were secured correctly onto the tower.		
b.	The OPGW runs along the inside of the tower or gantry leg.		
c.	The OPGW was strung with at least 5 m of slack available at ground level at the joint/ splice positions.		
d.	The OPGW has been cleated at 2 m intervals with appropriate clamps/ cleats, down to the ACD.		
e.	No slack in the OPGW exists between cleats.		
f.	No potential exists for abrasions to occur against the tower or gantry steel.		
g.	There is no unnecessary bird-caging; and where unavoidable, the birdcage has been pre-form wrapped.		
h.	The 5 m of spare OPGW has been coiled and securely mounted out of reach, prior to splicing. In the case of a gantry, the coil is mounted within the top quarter and diagonally within the leg; in the case of a tower, the coil is secured above the ACD.		
i.	An as-built diagram of the route, showing all towers where joints are positioned, and distances between joints and terminations has been submitted to the Engineer.		
j.	The OPGW was adequately bonded to earth within 2 m of the final position of the splice enclosure.		
2.	Installation of Ducting for Fibre Cable		
a.	50 mm flexible corrugated tubing has been laid between the FTP in the control room and the rigid/ flexible HDPE duct outside control room.		
b.	40 mm rigid HDPE duct has been laid from the control room to the manhole.		
c.	50 mm flexible duct has been laid from the manhole to the dome joint at the tower or gantry and passes through the vertical stainless tube to the approved splice enclosure.		
3.	Dome Splice Enclosures:		
a.	An approved splice enclosure has been used, according to the Specification.		
b.	The correct clamping ferrule, together with the correct half shells have been used at the base of the joint where the OPGW/fibre cable is clamped onto the splice enclosure.		
c.	An approved fusion splicer has been used.		
d.	The standard fibre numbering system has been applied during splicing.		
e.	The fibres have sufficient bending radius in the dome joint.		

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Item	Description	Date	Signature
f.	The correct splice enclosure was used (insulated vs. non-insulated).		
4.	Mounting of Splice Enclosures:		
a.	The coil and splice enclosure were secured above the anti-climb device in the correct position.		
b.	The correct stainless-steel bracket, (straight or right angled), was used to attach splice enclosure to the leg of tower or gantry.		
5.	Splice Enclosures between Sections of OPGW and Underground Cable:		
a.	5 m of spare coil has been retained inside the manhole.		
b.	The stainless-steel tube has been planted to a depth of 600 mm into the ground at the foot of the tower or gantry.		
c.	Expanding foam, such as 'Sista' or equivalent, has been used to seal the top of the stainless-steel tube, beneath the splice enclosure.		
d.	For gantries outside the substation, the coil and splice enclosure were mounted within the top quarter of the leg.		
e.	For towers outside the substation, the coil and splice enclosure were suitably mounted above the ACD.		
6.	Jointing of Fibre Cables at the FTP in the Control Room.		
a.	The 50 mm flexible corrugated ducting has been secured to the gland plate at the base of the FTP with a 50 mm male adaptor.		
b.	All fibres were spliced onto pigtails, and fibres on the splicing tray/ drawer have been neatly secured.		
c.	A standard fibre numbering system has been adopted as per the Specification/ Engineer's approval.		
d.	The cable into the tray/ drawer was tagged or labelled to display the substation name of the remote end of the link.		
e.	The front of the tray/ drawer has been correctly labelled, showing the fibre core numbers, and the source of the cable.		
7.	Final Testing of Links and Splices		
a.	The testing procedure (method statement) and settings of the OTDR machine have been provided by Contractor and approved by Employer's Agent (hold point for testing).		
b.	The red-light test (end-to-end test) and one-to-one testing of the fibres between the FTPs of adjacent substations has been witnessed (i.e., fibre 1 of FTP at Substation A connected to fibre 1 at FTP of Substation B, etc...).		
c.	The permitted total attenuation values for this link at 1310 nm and 1550 nm shall be less than: and This, has been achieved.		
d.	The OTDR tests of all fibres between the FTP of Substation A and the FTP of Substation B (in both forward and reverse directions) have been performed and it has been proven that the average attenuation losses and average splice losses are within the permitted limits, at 1310 & 1550 nm.		
e.	Fibre parameters for OTDR testing: i. Helix Factor: ii. Index of Refraction: iii. Rayleigh Backscatter Factor:		
f.	Both electronic and hardcopies of the OTDR reports have been submitted to the Engineer as per TE_CNINSTR009 and this Specification; including an attenuation analysis showing that the Specification has been achieved.		

Remarks

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Completed By:

	Contractor/Installer	Employer's Agent
Name:		
Signature:		
Company:		
Date:		

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ANNEXURE D: TECHNICAL DOCUMENTATION CHECKLIST

CLAUSE Ref.	PARTICULARS	UNITS
Have full and comprehensive details been submitted WITH the tender documents associated with each of the following items?		
Part A 3	Drawings of cable/conductor cross-section	Yes/No
Part A 8.7 & Part A 10	Quality systems of BOTH the SUPPLIER and the MANUFACTURER	Yes/No
Part A 13	Service Performance	Yes/No
Part A 14	Reliability	Yes/No
Part A 15	Training materials	Yes/No
Part A 16	Environmental considerations	Yes/No
Schedules	Completed Technical Schedule A and B	Yes/No

Completed By:

Name:	
Signature:	
Company:	
Date:	

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ANNEXURE E: FIBRE NUMBERING AND COLOUR CONVENTION

The standard colours of fibres in each bundle or tube shall be according to the latest revision of ANSI/TIA/EIA-598-D and IEC 60304 as follows:

TABLE F1					
Fibre Core	Fibre Colour/Tracer Code	Tube Colour Code	Fibre Core	Fibre Colour/Tracer Code	Tube Colour Code
Core 1:	Blue	Blue	Core 25:	Blue with Double Black Tracer	Slate/Grey
Core 2:	Orange		Core 26:	Orange with Double Black Tracer	
Core 3:	Green		Core 27:	Green with Double Black Tracer	
Core 4:	Brown		Core 28:	Brown with Double Black Tracer	
Core 5:	Slate/Grey		Core 29:	Slate/Grey with Double Black Tracer	
Core 6:	White		Core 30:	White with Black Tracer	
Core 7:	Red	Orange	Core 31:	Red with Double Black Tracer	White
Core 8:	Black		Core 32:	Clear with Double Black Tracer	
Core 9:	Yellow		Core 33:	Yellow with Double Black Tracer	
Core 10:	Violet		Core 34:	Violet with Double Black Tracer	
Core 11:	Pink		Core 35:	Pink with Double Black Tracer	
Core 12:	Aqua/Turquoise		Core 36:	Aqua/Turquoise with Double Black Tracer	
Core 13:	Blue with Black Tracer	Green	Core 37:	Blue with Triple Black Tracer	Red
Core 14:	Orange with Black Tracer		Core 38:	Orange with Triple Black Tracer	
Core 15:	Green with Black Tracer		Core 39:	Green with Triple Black Tracer	
Core 16:	Brown with Black Tracer		Core 40:	Brown with Triple Black Tracer	
Core 17:	Slate/Grey with Black Tracer		Core 41:	Slate/Grey with Triple Black Tracer	
Core 18:	White with Black Tracer		Core 42:	White with Triple Black Tracer	
Core 19:	Red with Black Tracer	Brown	Core 43:	Red with Triple Black Tracer	Black
Core 20:	Clear with Black Tracer		Core 44:	Clear with Triple Black Tracer	
Core 21:	Yellow with Black Tracer		Core 45:	Yellow with Triple Black Tracer	
Core 22:	Violet with Black Tracer		Core 46:	Violet with Triple Black Tracer	
Core 23:	Pink with Black Tracer		Core 47:	Pink with Triple Black Tracer	
Core 24:	Aqua/Turquoise with Black Tracer		Core 48:	Aqua/Turquoise with Triple Black Tracer	

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ANNEXURE F: LOOSE TUBE DUCT CABLE COLOUR CODE ACCORDING TO ANSI/TIA/EIA-598-D

No. of Fibres	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8
24 (4x6)	Blue	Yellow*	Orange	Yellow*	Green	Yellow*	Brown	Yellow*
48 (8x6)	Blue	Orange	Green	Brown	Grey	White	Red	Black

N.B. Yellow* - Filler/Loose buffer tube without fibres