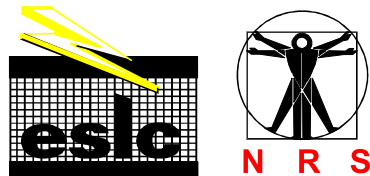


# **SPECIFICATION FOR OVERHEAD GROUND WIRE WITH OPTICAL FIBRE**

## **Part 2: Installation guidelines**



This rationalized user specification is issued by  
the Technical Governance Department, Eskom,  
on behalf of the  
User Group given in the foreword  
and is not a standard as contemplated in the Standards Act, 1993 (Act No. 29 of 1993).

**Table of changes**

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**Foreword**

This part of NRS 061 was prepared on behalf of the NRS Association and approved by it for use by supply authorities.

This part of NRS 061 is based on TRMASACB2:2000 and was compiled by M Korber and B Jacobs. Annex B is based on TPR 0150 compiled by D C Smith (Eskom).

This part of NRS 061 was prepared by a working group comprising the following members:

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A Manufacturers Interest Group (MIG) was also consulted on the contents of this part of NRS 061 and its comments were incorporated where the working group was in agreement. The MIG comprised the following members:

C Horn	Letacla
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Annexes A, B and C are for information only.



## **Introduction**

This part of NRS 061 was prepared to establish and promote uniform requirements for the installation of overhead ground wire with optical fibre.

The NRS Association expresses the wish that, in the national interest and in support of government policy to foster local manufacture and stimulate export, all purchasers adopt the requirements of this part of NRS 061 insofar as their particular conditions will allow.

## **Keywords**

Optical ground wire.

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## OVERHEAD GROUND WIRE WITH OPTICAL FIBRE

### Part 2: Installation guidelines

#### 1 Scope

This part of NRS 061 specifies the installation of overhead fibre links between patch panel enclosures at the two terminating substations. It also specifies the essential methods for stringing, tensioning, earthing, jointing and terminating of the overhead ground wire with optical fibre (OPGW).

#### 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of NRS 061. All normative documents are subject to revision and, since any reference to a normative document is deemed to be a reference to the latest edition of that document, parties to agreements based on this part of NRS 061 are encouraged to take steps to ensure the use of the most recent editions of the normative documents indicated below. Information on currently valid national and international standards can be obtained from Standards South Africa.

CIGRE TF 22.11.03, *Guide to fittings for optical cables on transmission lines – Part 1: Selection and use.*

IEC/TR 61328:2003, *Live working – Guidelines for the installation of transmission line conductors and earth wires – Stringing equipment and accessory items.*

SANS 60793-1-40/IEC 60793-1-40:2001 (SABS IEC 60793-1-40), *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation.*

SANS 61230/IEC 61230:1993, *Live working – Portable equipment for earthing or earthing and short-circuiting.*

NRS 088-2, *Duct and direct-buried underground fibre-optic cable Part 2: Installation guidelines*

#### 3 Terms, definitions and abbreviations

For the purposes of this part of NRS 061, the following terms, definitions and abbreviations apply.

##### 3.1 Terms and definitions

**acceptable**

acceptable to the customer

**birdcaging**

loosening and separation of the outer layer wires from the inner wires

**ghosting**

false reflection which appears at an integral multiple of the distance from the initial (true) reflective event, for example if a large reflection occurs at say 1 000 m, there could be a ghost at 2 000 m due to the reflected light bouncing back and forth within the fibre

**residual strength**

remaining tensile strength of the conductor after it has been in service

**splicing**

fusion of the ends of two fibres to create a joint with minimal optical loss

**running blocks**

a pulley assembly used to facilitate the stringing of OPGW cable

## **3.2 Abbreviations**

**3.2.1 ACS:** aluminium clad steel

**3.2.2 AGS:** armour grip suspension

**3.2.3 HDPE:** high-density polyethylene

**3.2.4 IP:** ingress protection

**3.2.5 MFD:** mode field diameter

**3.2.6 NCS:** national calibration standard

**3.2.7 OPGW:** overhead ground wire with optical fibre

**3.2.8 OTDR:** optical time domain reflectometer

**3.2.9 UTS:** ultimate tensile strength

## **4 Requirements**

### **4.1 General**

The stringing of OPGW is analogous to the stringing of the standard ground wire but the presence of the optical fibre core implies the adherence to special protection measures to prevent damage to the fibres due to mechanical elongation, bending, twisting and crushing forces. This part of NRS 061 describes the measures required to correctly install OPGW on overhead transmission lines in such a way that a long service life is guaranteed and that there will be no danger to either the public or personnel involved in this process.

### **4.2 Preparatory work**

It is essential that the installer is completely familiar with the requirements of the cable manufacturer. To ensure the integrity of the fibre optic core during stringing, the following preparatory work is essential:

- a) OPGW drum lengths should be carefully selected for the specific line sections to be strung to avoid the necessity of installing splice enclosures on towers where the OPGW must be insulated from the steelwork as much as possible. Allowance should be made for sag and winch tensioner take-up. If profile drawings are not available then a physical site inspection should be organized to verify if the winch and tensioner positions are suitable from a topographical point of view. There could be trenches, no access, swamps, etc). Joint positions and drum lengths should be approved by the employer.
- b) The drums should be transported to the designated material holding area in a vertical position with the cable ends fixed and sealed so that no moisture can affect the cable. Drums should remain in the vertical position during unloading so that the drum is not damaged. Under no circumstances should the drums be placed on their sides.

The drums should be stored far from any activity that could damage the cable in order to facilitate the handling and loading. To minimize the risk of fire, the storage area should be cleared of all vegetation.

- c) After selection of suitable locations for the tensioner and puller (which should be done prior to ordering cable (see point 4.2 (a) above) and only when approved by the employer, OPGW drums, fittings and accessories, they should be transported to the site and kept in a suitable place until their final use.

### **4.3 OPGW stringing**

#### **4.3.1 Special tooling and precautions needed for OPGW stringing**

**4.3.1.1** All the provisions for controlled stringing should be in accordance with IEC/TR 61328. The equipment earths should be in accordance with SANS 61230. Figure C.1 shows the recommended equipment necessary for OPGW stringing.

**4.3.1.2** Hydraulic pullers equipped with dynamometers should have a pulling capacity at least 1,5 times the stringing tension. The pullers should be properly anchored to resist any lifting forces during stringing.

**4.3.1.3** A tensioner equipped with dynamometers that have a bull wheel 1,2 m or more in diameter should be anchored to prevent any uplift force.

**4.3.1.4** Drum jacks of suitable capacity should be used on both sides of the drum so that the drum can rotate freely without touching the ground. Drum jacks should have braking arrangements to ensure that rotation stops smoothly.

**4.3.1.5** Anti-twisting counterweights that consist of a series of weights linked by hinges should be applied if recommended by the manufacturer. Suggested weights for the anti-twisting devices are as follows, but in all cases, the manufacturer's recommendation will take preference.

:

- a) 12 kg for span lengths up to 300 m;
- b) 15 kg for span lengths from 300 m to 700 m; and
- c) 20 kg for span lengths of more than 700 m.

**4.3.1.6** Swivels should be rated appropriately and of dimension to easily pass through running blocks.

**4.3.1.7** Neoprene or similar material lined pulley guides (sheaves) diameter should be a minimum of 450 mm for intermediate, and 600 mm for strain structures. A single wheeled running block should be used if the line angle and the OPGW angle are less than 60°. If the angle is greater than 60°, a twin wheeled running (wheels placed in tandem) block will be necessary (see figure C.2).

**4.3.1.8** Suitable pulling grips should be used for the different construction of OPGW cable in accordance with the manufacturers' instructions.

**4.3.1.9** Pre-stretched polyester and steel ropes should be used. Suitable anti twist and non-stretch pulling rope should be used with a breaking load at least 1.5 times the installation tension. The pulling rope should be in accordance with clauses 5, 6 and 7 of the "Driven Machinery Regulations" of the OHS Act.

#### **4.3.2 Stringing operation**

**4.3.2.1** To protect the integrity of the optical fibres and the armouring during stringing, the requirements in 4.3.2.2 to 4.3.2.8 (inclusive) should apply.

**4.3.2.2** The minimum diameters of the tensioner reels (on which the OPGW will be coiled during installation) should be at least 70 times the diameter of the OPGW being installed, or as specified by the manufacturer. The bull wheel sheave diameter should be more than 70 times the cable diameter or 1 200 mm, whichever is larger. The wheels should be in such condition that they do not have any burrs or cavities which may damage the cable. The running grooves should be adapted in size to the cable diameter. At best, they should be

coated with neoprene or similar material. The tensioner should be able to assure constant tension and allow a steady slow down at different stringing speed without the effect of cable run after. Tensioning should be readily controllable and capable of maintaining constant and even operation. There should be a minimum of 4 turns to anchor the cable. To prevent birdcaging, the correct orientation for entry and exit of the cable should be considered. For right-hand lay, the cable should enter the brake on the left and exit on the right. For left-hand lay, the cable should enter on the right and exit on the left.

**4.3.2.3** The distance from the winch to the first pulley on the tower should be at least twice the height of the pulley attachment point.

**4.3.2.4** The first and last tower in the section and at towers with an angle of deviation between 15° and 60°, the pulley diameter should be at least 800 mm. If the angle is greater than 60°, a twin running block (wheels placed in tandem) should be used (see figure C.2). Cable manufacturers' guidelines should always take precedence when running block diameters are selected.

**4.3.2.5** The stringing should be carried out using winches with settable pulling force limitations and automatic shutdown facility. The pulling force should be monitored and the maximum pulling tension should be as specified by the cable manufacturer thereby ensuring that no damage is caused to the cable or structure. The winch should be checked for correctness of pulling force before the start of stringing.

**4.3.2.6** The stringing speed should not exceed 30 m/min but depending on the stringing conditions this could change. The winch should be started slowly at the minimum speed and the speed increased gradually to the maximum speed. When the anti-twisting device is approaching the pulley, the stringing speed should be decreased to 5 m/min.

**4.3.2.7** For new lines, the OPGW stringing operation will be governed by other construction activities such as erection of the towers and stringing of phase conductors. For existing lines, where the earth conductor is substituted by the OPGW, the earth conductor may be used as a pilot cable wire if it is in good condition and if the specific pulling force does not exceed the residual strength of the conductor. In both cases the stringing should be carried out in accordance with 4.3.1. For lines without earth wire, the pulling rope should be installed first and then the OPGW installed using the standard method shown in figure C.1.

**4.3.2.8** The bull wheels of the tensioner should be provided with a neoprene layer when the outer layer of the OPGW is made up of aluminium clad steel, aluminium or aluminium alloy.

**4.3.2.9** Vibration dampers in accordance with 4.4.6.4 should be accurately positioned according to the agreed design for the specific line.

### **4.3.3 Special conditions during stringing**

**4.3.3.1** Where specified by the manufacturer of the OPGW, anti-twisting counterweights should be used to protect the optical fibres against excessive twisting action during the stringing operations. An anti-twisting counterweight should be installed at the front end of the OPGW. If, subject to the requirements described in 4.3.1.5, more than one anti-twisting counterweight should be used, then the anti-twisting counterweights should be located as shown in figure C.1. Anti-twisting counterweights and pulleys should be compatible. The anti-twisting counterweights should pass through the pulley at reduced speed.

**4.3.3.2** Care should be taken to ensure that the cable is not damaged by dragging it along the ground or over any objects.

**4.3.3.3** In order to prevent the OPGW from being damaged, sagging, clamping and installation of fittings should only be performed after a short settling period. The installer should be responsible for any damage caused to the cable if this subclause is ignored.

**4.3.3.4** OPGW should be strung and tensioned with minimum mechanical impact. The minimum bend radius should not be less than that specified by the OPGW supplier.

**4.3.3.5** A protective sleeve should be inserted around the conductor for a length of 5 m, where the anti-twisting devices are positioned on the conductor. Subsequently, the conductor portion where the anti-twisting device was attached, should be removed.

**4.3.3.6** Owing to induction effects from power lines, running earths should be provided to ensure personnel safety (see IEC/TR 61328).

**4.3.3.7** Should it be necessary to leave the OPGW in the pulleys for an extended period during construction (greater than 48 hours), portable earths should be applied on the OPGW at every tower where the OPGW passes over a pulley. Care should be taken in the application of such earths not to damage the OPGW cable.

**4.3.3.8** Should it be necessary to leave the OPGW in an incomplete installation for an extended period during construction (greater than 48 hours), any coils of cable including cable on the drum should be safely earthed.

#### **4.3.3.9 Conductor Cars (only if allowed by the customer's safety regulations)**

For installation of special devices like warning spheres or for maintenance reasons it may be necessary to use a conductor car on the cable. To ensure safety of personnel and to prevent damages to the cable the following rules must be followed:

All cables with two or more armouring layers and an ACS or galvanised steel content of at least 25 mm<sup>2</sup> can be considered as appropriate. The conductor car must be equipped with at least two wheels with a minimum diameter of 25 cm which are permanently carrying the car. If the diameter of the wires in the outer layer is smaller than 3,0 mm, the wheels must be lined with an elastomer to protect the surface wires from damage.

In case of bigger wires the wheels can also be made of aluminium or plastic (e. g. PA). The groove must be rounded at the bottom with a radius bigger than the radius of the OPGW. To prevent pinching of the cable there must be adequate clearance at the sides of the groove.

By means of sag calculation with appropriate software it must be ensured that under no condition the Permissible Maximum Working Tension of the cable is exceeded. If there are stricter safety regulations given by the government, the power utility or the installation contractor, these safety procedures will take precedence over the limit given above. In case of an existing (older) installation it must be ensured that the cable is not damaged to a degree which influences the safety.

The weight of the conductor car is very important for tension and maximum sag limits. For that reason in any case it should be the lowest possible. The maximum weight for steel tube cable is limited to 250kg.

#### **4.3.4 Jointing and splicing between two sections of OPGW**

**4.3.4.1** The correct number of correctly dimensioned down-lead clamps should be used at each down-lead cable to ensure that the OPGW is securely anchored to the tower in such a way as to eliminate vibrations and cable clashing against the tower. A down-lead clamp should be installed at each tower member intersection. The distance between clamps should be as specified in 4.4.6.5. Clamp bolts should be tightened using torque wrenches. The torque that will prevent damaging stress concentrations due to clamping should be obtained from the OPGW and clamp manufacturers. Only clamps approved by the OPGW manufacturer should be used.

On insulated strain (see figure C.3) or suspension towers, the down-lead should be insulated from the tower using insulated clamps. The minimum distance between the OPGW and any tower member should be greater than or equal to 50 mm.

On non-insulated strain (see figure C.4) or suspension towers, the down-lead should be electrically connected to the tower by means of non-insulated clamps.

**4.3.4.2** Upon completion of section stringing, if optical fibre cables are hand fed through the tower structure, the minimum bending radius specified by the manufacturer, should not be compromised and care should be taken to avoid birdcaging.

**4.3.4.3** Upon completion of stringing, sufficient spare cable should be available to permit jointing to take place. The length of the OPGW for connection purposes should allow sufficient slack from the strain clamp to permit splicing at ground level and at the same time to preserve the manufacturer's recommended bending radius (see figure C.6). A further minimum allowance of 25 m should be provided in each enclosure to make fibre optic connections of which the last 10 m should be cut away and disposed of in an environmentally approved manner. In areas where there is a high risk of vandalism, jointing should be done higher up on the tower. The basic requirements for hardware at splicing towers and standard towers as well as for insulated and non-insulated assemblies are depicted in figures C.3, C.4, C.5, C.6, C.7, C.8 and C.9. If splicing is required at either strain towers or suspension towers, the tension assemblies as shown in figures C.3, C.4, C.9A and C.9B should be used, depending on whether insulated assemblies are required or not.

All joint boxes should be mounted as high in the tower as practical, to avoid theft. It should be ensured that the mounting height of the joint box is such that the safe working clearance from any of the phase conductors to the joint box is not less than the distance as specified below:

765kV	-	6,0 metre + 1 metre = 7,0 metre
400kV	-	4,0 metre + 1 metre = 5,0 metre
275kV	-	3,0 metre + 1 metre = 4,0 metre
220kV	-	2,5 metre + 1 metre = 3,5 metre
132kV	-	2,0 metre + 1 metre = 3,0 metre
88kV	-	1,5 metre + 1 metre = 2,5 metre
66kV	-	1,3 metre + 1 metre = 2,3 metre
1 to 44kV	-	1,0 metre + 1 metre = 2,0 metre

**4.3.4.4** If OPGW sagging and jointing cannot be done in a continuous operation, the ends of the OPGW should be sealed using a suitable heatshrink end cap for fibre tube sealing and the ends must be mechanically secure to prevent unwinding of strands and that should remain in place until jointing work starts. Spare lengths of OPGW at jointing tower should be coiled in coils not transgressing the minimum bending radius of the cable. The coils should be securely attached, above the anti-climbing devices, to the tower in order to prevent OPGW damage under windy conditions as well as to prevent theft. Refer to 4.3.3.7 and 4.3.3.8 for temporary earthing arrangements. For monopoles, suitable brackets should be approved by the employer.

**4.3.4.5** Well-trained technicians should carry out splicing of optical fibres. Splicing machines should be capable of creating splices consistently better than an average of 0,05 dB. Tools and measuring equipment should be provided and used for each splice. Splicing should be done at ground level unless otherwise specified by the customer, after which the splice enclosure should be fixed on the tower above the anti-climbing device. Splice losses should be as stated in annex B, unless otherwise specified by the customer.

The operation of splicing should follow the following sequence:

- fix an adapter for the mounting of the splice enclosure onto the tower; for an insulated OPGW strain assembly the splicing enclosure should be insulated from the tower structure; for a non-insulated OPGW strain assembly the splicing enclosure should be electrically bonded to the tower structure;
- fix the OPGW temporarily into position and mark the OPGW where the joint must be clamped. This is to prevent uneven OPGW downleads that make the installation untidy;
- remove the outer strands and expose the optical fibre unit in accordance with the splice enclosure manufacturer's instructions;
- clamp the OPGW as specified by the splice enclosure manufacturer;
- splice the optical fibres by fusion;



- e) reinforce the splicing point with heat shrinkable tube or by other means in accordance with the splice enclosure manufacturer's instructions;
- f) secure and lay the optical fibres in the splice organizer inside the enclosure on completion of a permanent splice;
- g) close and seal the splicing enclosure; and
- h) loop the excess cable and secure the splice box to the adaptor mounted onto the tower, to ensure that the minimum bending radius specified by the manufacturer is adhered to and that there is no birdcaging.

#### **4.3.5 Jointing and splicing between OPGW and underground fibre cables**

The termination of OPGW into substations should be by means of a standard, non-insulated strain assembly.

**4.3.5.1** The OPGW should be attached to the gantry or alternatively a terminal tower, using an earth bond which is connected to the OPGW by means of a suitably rated earthing device. On the other end of the earth bond, a crimped lug should be fitted to enable the earth bond to be bolted to the steelwork and which guarantees a proper current path. Dedicated earthing should be required on all non-insulated assemblies.

**4.3.5.2** Metallic, non-insulated clamps should be used to attach the down-leads to steelwork.

**4.3.5.3** The OPGW should be clamped at every intersection with steelwork using approved hardware. It is recommended that where possible, the OPGW be clamped on the outside of a substation gantry structure and not threaded through the structure.

**4.3.5.4** The termination enclosure linking the underground cable to the OPGW may be required at the terminal tower or gantry. In these situations the end of the HDPE tubing housing the underground fibre cable should be sealed to prevent the ingress of water and rodents. The termination enclosure should be secured and mounted in accordance with the requirements of the customer.

**4.3.5.5** Any loops of slack cable for both the OPGW and the underground cable should be properly secured using suitable clamps (downlead clamps). PVC ties will not be allowed.

**4.3.5.6** A general layout is shown in figure C.9.

#### **4.3.6 Completing the OPGW connection to the termination room**

**4.3.6.1** The fibres from the OPGW should in all cases be spliced directly to the underground duct cable leading to the patch panel, in the splice box at the tower or gantry. The fibres should be terminated as required at the patch panel enclosure provided at the termination end. Minimum cable bending radius requirements should be observed at all times.

**4.3.6.2** This duct cable should be run, where possible, physically separated from the other control cables in the cable trenches provided.

**4.3.6.3** This can be achieved in one of two ways. The duct cable may be constructed with or without armouring, though the use of unarmoured cable in HDPE duct is recommended.

- a) Using unarmoured duct cable

Unarmoured duct cable should be laid inside class 6 high-density polyethylene (HDPE) duct or similar of approximately 50 mm diameter.

Should a joint be required in the HDPE duct, a high pressure connector should be used to protect against damage by rodents and ingress of moisture.

b) Using armoured duct cable

In a conventional substation arrangement where there is a common earth mat for the entire area and where armoured cable is specified, CST armoured optical fibre duct cable should be used for the link between the OPGW splice enclosure installed at the gantry or terminal tower at the line entry and the patch panel enclosure in the termination room. The armouring should be used for mechanical protection and should never, even unintentionally, be used as a current-carrying conductor. The armouring should always be cut well back ( $\pm 100$  mm) and the end insulated with heat-shrink sleeving at the two ends where the cable enters the cable compression glands at the splice enclosure at one end and the patch panel enclosure cabinet gland plate at the other, to prevent accidental connection to either earth or to personnel.

**4.3.6.4** If the cable run is very long, the armouring should be removed for a length of 150 mm for every 250 m of cable length. This isolation section should be covered by an appropriate cast resin joint arrangement.

**4.3.6.5** Armoured duct cable should never be used where the two ends are on separate earth mats.

#### **4.3.7 Underground interconnection of two OPGW sections**

The OPGW should be treated in accordance with 4.3.5 at the two line terminal towers. The underground section should be constructed in accordance with NRS 088-2.

### **4.4 Fittings**

#### **4.4.1 General**

**4.4.1.1** No holes will be drilled into the tower steelwork for any hardware provided.

**4.4.1.2** All hardware should be approved by the OPGW supplier and customer (see CIGRE TF 22.11.03). Hardware assemblies, including down-lead clamps, for the OPGW should be compatible with the cable to ensure that the system so formed will survive the operating environment for the design life. All items of hardware should conform to specified requirements. The hardware component supplier should be fully responsible for his designs and their satisfactory performance in service. Approval by the customer does not relieve the supplier of responsibility for the adequacy of the design, dimensions and details.

**4.4.1.3** Suspension and strain assemblies should be designed so that line contact between coupled components occur. Point contact between components should be avoided.

#### **4.4.2 Drawings**

Drawings of assemblies offered should be supplied and should indicate for each component

- a) the material type,
- b) the material grade (and heat treatment where applicable),
- c) the strength rating,
- d) tolerances (where applicable), and
- e) dimensions.

#### **4.4.3 Tolerances**

Dimensions of all items of hardware should be subject to the tolerances specified in the referenced standards. Where no standard or tolerance is referenced, the fit tolerance should be  $\pm 2\%$  of the dimension. All tolerances should be subject to the customer's approval. Items of hardware found to be out of tolerance should be rejected.

#### **4.4.4 Materials**

##### **4.4.4.1 Materials for OPGW**

The material and construction of the OPGW should be specified as given in the relevant contract.

##### **4.4.4.2 Materials for fittings, tension and suspension assemblies, earthing devices and downlead clamps**

The choice of material for tension and suspension assemblies, downlead clamps as well as the earthing device, should be specified by the OPGW manufacturer to match the material of the OPGW and will take precedence over this part of NRS 061. In all cases, internationally accepted standards should be complied with.

In general, if the OPGW outer layer is of steel, the fitting material should be of steel material. When the OPGW outer layer is of aluminium material, the fitting material should be of an aluminium alloy material. In cases where the OPGW outer layer is of aluminium clad steel, the fitting material should be of steel material. See 5.1 for tensile type test.

In all cases the correct lay direction of the fittings in relation to the OPGW should be observed. Normally the lay direction of the fitting wire is opposite to the outer OPGW layer direction.

##### **4.4.4.3 Materials for grounding cable or earth bonds**

The type of material and size should be adequate to safely handle the required short-circuit rating and requirements of the OPGW as specified. The choice of material should also depend on compatibility with the OPGW and current transfer tab material in order to prevent galvanic corrosion.

#### **4.4.5 Installation procedures**

Details of installation procedures of hardware assemblies and down-lead clamps should be supplied both with a tender offer and with each batch delivered where requested.

#### **4.4.6 Hardware**

##### **4.4.6.1 Tension assemblies**

Tension assemblies should comply with the following requirements:

- a) Tension assemblies should be of the helical pre-formed type (see figures C.3, C.4 and C.7).
- b) When selecting hardware for OPGW, great care should be taken not to apply excessive stresses on the conductor that will affect the OPGW core.
- c) Tension assemblies should withstand the fault current design parameters.
- d) Where the OPGW must be joined at a splicing tower, a ground cable should be installed between the two spans to ensure electrical continuity between the two. Connection to the OPGW should be by means of a current transfer tab, embedded in the armour rods that is protecting the OPGW or via a correctly –sized clamp or helical pre-formed fitting.

- e) In the case of an insulated strain assembly (see figure C.3) the ground cable should be insulated from the tower. Depending on the geometry of the tower, using a support or stand-off insulator will prevent contact between OPGW and tower steelwork under all environmental operating conditions.
- f) The creepage of the insulation material should be equal to or more than 50 mm.
- g) At the terminal tower, the OPGW may or may not be earthed, in accordance with local practice.

#### 4.4.6.2 Suspension assemblies

Suspension assemblies should comply with the following requirements:

- a) Only AGS type assemblies with a neoprene insert, or similar approved, should be accepted (see figure C.10).
- b) Suspension assemblies should withstand the fault current design parameters.
- c) Non-insulated suspension assemblies should be fitted with a ground cable to ensure proper grounding between the OPGW and the tower steelwork. Connection of the ground cable to the OPGW should be by means of a current transfer tab or flag, embedded in the armour rods that are protecting the OPGW.

#### 4.4.6.3 Grounding connectors (jumpers, ties or earth bonds)

The ground cable installed between the OPGW and the tower steelwork, or between two spans across a tower, should be connected to the OPGW by means of a current transfer tab or flag, embedded in the armour rods protecting the OPGW and which will ensure proper mechanical and electrical connection or via a correctly –sized clamp or helical pre-formed fitting. The other end of the ground cable should be fitted with a crimped lug or fitting which can be connected to the tower, using one of the tower bolts. Before connecting the crimped lug or fitting to the tower members, the tower steelwork should be cleaned to remove paint or grease (or both) to ensure proper electrical connection. After connection the exposed area(s) should be repainted or cold galvanized to prevent corrosion of the tower steel members. The arrangement for terminating and earthing of the OPGW at the substation gantry is depicted in figure C.11.

The OPGW should be correctly bonded to earth at the terminal station gantries and at all non-insulated earthwire towers. Type Test Certificates for proposed earth bonds should be available on request. The type of material and size will be adequate to safely handle the required short circuit rating and requirements of the OPGW as specified. The choice of material should also consider compatibility with the OPGW and current transfer tab, not to initiate galvanic corrosion.

All earth bonds should be of the flexible type and be corrosion resistant. Earth bonds should be of sufficient length to connect the OPGW to the tower steel work. To accommodate this, one end of the earth bond should be fitted with a crimped lug enabling connection to the tower steel work by means of an M16 bolt. Before connecting the crimped lug or fitting to the tower members, the tower steelwork should be cleaned to remove paint or grease (or both) to ensure proper electrical connection. After connection the exposed area(s) should be re-painted or cold galvanized to prevent corrosion of the tower steel members. The other end of the earth bond should be fitted with a suitable clamp arrangement for connection to the OPGW.

The pre-formed type “pig tail” earth bond is not acceptable. However connection of the earth bond to the OPGW or OPGW armour rods by means of pre-formed helical attachment, a current transfer tab or a parallel groove type (PG clamp) connection, will be acceptable on condition that results of electrical testing be submitted. The electrical testing should be performed not on the earth bond in isolation but on the complete connected assembly including the OPGW simulating a typical fault current in field conditions. The type of material and size should be adequate to safely handle the required short circuit rating requirements of the OPGW as specified. The choice of material should also consider compatibility with the OPGW not to initiate galvanic corrosion. When using parallel groove type clamps, the design should be such that no excessive stresses, that will affect the performance of the OPGW under any circumstances, will be induced.

The companion earthwire should be continuous from gantry to gantry. It may be necessary to install additional jumper straps on this earthwire. The contractor should allow for this eventuality, and perform the necessary work.

#### **4.4.6.4 Aeolian vibration dampers**

Vibration dampers that are capable of damping any aeolian vibration that the OPGW may experience, should be used. The type, size, mass, quantity and spacing of vibration dampers should be selected to limit the aeolian vibration bending amplitude so that the safe bending amplitude as prescribed by the OPGW manufacturer is not exceeded. Only multi-frequency type Stockbridge dampers may be used.

#### **4.4.6.5 Down-lead clamps**

The design of down-lead clamps should be such that no excessive stresses, which will affect the performance of the OPGW under any circumstances, will be induced.

Two options exist, namely insulated down-lead clamps and non-insulated down-lead clamps. The type to use will depend on whether the hardware assemblies, connecting the OPGW to the tower, are insulated or non-insulated.

Down-lead clamps should be installed at every tower steelwork intersection and should be not more than 2 m apart.

#### **4.4.6.6 Non-insulated down-lead clamps**

Non-insulated down-lead clamps should ensure proper electrical connection between the OPGW conductor and the tower steelwork. When attaching the clamp to the tower steelwork care should be taken to ensure electrical connection and that mechanical damage, which in turn could lead to corrosion damage, will not be imposed on the tower steelwork. Materials used for the down-lead clamp should be such that galvanic corrosion will not start between the down-lead clamp and the tower steelwork.

A sufficient number of down-lead clamps should be used to ensure sufficient support of the OPGW along the tower. This support should be in such a manner that the OPGW will not clash with any part of the tower steelwork as a result of wind or due to its own mass if strung or laid in a horizontal configuration.

#### **4.4.6.7 Insulated down-lead clamps**

The requirements for the insulated down-lead clamps are exactly the same as those for the non-insulated down-lead clamps in 4.4.6.6, except that no electrical contact between the OPGW and tower steelwork should occur. In all cases a minimum distance of 50 mm should exist between the OPGW and tower steelwork.

#### **4.4.6.8 Splicing enclosure (joint enclosure)**

All construction details and IP ratings of the proposed units should be provided. The splicing enclosures should be supplied with tower earth bonding fixtures. They should facilitate fibre organization and splicing requirements and should be vandal resistant if specified.

As far as possible, the use of insulated splice enclosure installations should be avoided.

#### **4.4.6.9 Earthwire insulators**

The earthwire insulator should comply with the parameters given in table 1.

**Table 1 — Earthwire insulator parameters**

1	2
Shed material	Silicone-based
Standards	Comply with IEC60815, IEC61109
Corecover thickness	≥ 3 mm
Insulator class	Class A
Connecting length	375 (±12) mm
Creepage length	≥ 174 mm
Pf. Dry, one minute withstand	50 kV (without arcing horns)
Pf. Wet, one minute withstand	25 kV (without arcing horns)
Lightning positive impulse withstand	80 kV (without arcing horns)
Minimum mechanical strength	120 kN
Coupling method	In-line tongue and clevis caps in accordance with IEC 60471 size 16L
Arcing horn shape	“Jacob’s Ladder” with minimum strait horn lengths of 50 mm and an angle of 60± 5 degrees between them
Arcing horn bending radius	≥ 2 times the arcing horn rod/bar diameter at base
Arcing horn material	Hot dipped galvanized forged steel
Arcing horn cross sectional area	> 18 mm <sup>2</sup> each
Arcing horn gap size	8 (± 2) mm fixed

## 4.5 Safety and environmental

### 4.5.1 General

Contractors should be authorized by the local utility or by some other official capacity, for example, in terms of the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) (OHS Act), for preparation of the earth wire for stringing purposes under energized conditions and stringing under de-energized conditions.

The stringing tension used should be such that adequate clearance is maintained at all times.

### 4.5.2 Safety requirements

Requirements of the local operating regulations and the said OHS Act should apply.

The following requirements should also apply:

- Staff should meet prerequisites, and should be sufficiently trained, evaluated and authorized accordingly.
- Lifting machines and equipment should comply with said OHS Act requirements.
- Access and keys should be controlled in accordance with local operating instructions.
- Permit system or workers register system of controlling staff should be enforced in accordance with local operating instructions.
- Risks should be identified, evaluated and eliminated or managed to an acceptable level.
- Safe working electrical clearances should be maintained at all times.
- Precautions against induction and system fault current in the form of equipotential earthing and bonding should be enforced. This includes running earths, fenced winch or tensioner operator equipotential zones and bonding at tower earth peaks. All portable earths should comply with the requirements of SANS 61230.
- Suitable personal protective equipment should be used.

- i) Tools and equipment should be correctly selected and applied.

#### **4.5.3 Environmental requirements**

All work should be performed in compliance with environmental legislation.

The following requirements should also apply:

- a) There should be minimal impact and disturbance of the environment.
- b) Agreements and relationships with landowners should be adhered to. This includes notification before arrival and ensuring access gates are left the way they were found.
- c) All fibre off-cuts should be disposed of in an environmentally safe manner.

#### **4.6 Quality control**

The quality control requirements should be specified by the customer.

### **5 Tests**

#### **5.1 Tensile type test**

A tensile type test should be performed on the OPGW, together with the line hardware to be used on the actual system, to prove that the combination will achieve a tensile performance of a minimum of 95% of the stated UTS of the OPGW cable. A type test report, witnessed by the customer or its appointed representative(s), should be submitted after tender award and prior to installation.

NOTE 1 The contractor should ensure that when the relevant strain hardware and OPGW cable are tested and eventually installed, the relative movement between inner and outer layers (in the case of a multi-layer construction) should be the minimum possible. This may either be achieved by selecting the appropriate cable construction for the intended hardware to be used or by selecting appropriate hardware for the suggested cable construction.

NOTE 2 The OPGW cable and hardware may be considered to be a system. The contractor should therefore supply the hardware correctly matched to the OPGW cable to minimise installation and operational problems during the life of the cable, under all conditions.

#### **5.2 Optic fibre site tests before installation**

**5.2.1** The integrity and attenuation of individual fibres should be tested with the OPGW still on the drums, before stringing.

The test should be performed for each fibre in the OPGW at two wavelengths, 1 310 nm and 1 550 nm from one direction only. When requested, testing should be witnessed by the customer representative.

**5.2.2** The identity of individual fibres should be clearly marked.

**5.2.3** The results of the tests should be produced in table 2. The table heading should contain the drum number and the length of the OPGW.

**5.2.4** The table should record the attenuation for each fibre. Results should be produced in paper and digital format (disc).

**5.2.5** If the drum test was successful, the drum should be handed over to the main contractor. In the case of failure the drum should be returned to the supplier, and all costs associated with the replacement of the defective material should be for the supplier's account.

**5.2.6** Unless otherwise specified in the project requirements, the main contractor should be held responsible for the proper protection and safekeeping of the OPGW drums until the completed transmission line is taken over by the customer and any surplus material has been returned to the customer. The contractor should be held responsible for any loss or damage to material required for or surplus to, the contract works.

All material received should be neatly stored in properly defined storage areas to facilitate checking of quantities and quality. Receipt slips should be forwarded to the customer within two days of delivery, and a record of the total quantities of material received and used, should be kept on site.

**Table 2 — Optic fibre site test results before installation**

1	2	3	4	5	6
Project			Drum number		
			Loss dB/km		
Tube	Fibre	Colour	1 310 nm	1 550 nm	Length
1	1				
	2				
	3				
	4				
	5				
	6				
2	1				
	2				
	3				
	4				
	5				
	6				

### 5.3 Testing after completion of installation

After completion, the OPGW should be tested for integrity and attenuation of the optical fibres. All joints should be of the fusion type and the average loss per splice for the entire route should be less than that specified in annex B, unless otherwise specified by the customer. Test results should be recorded and presented as shown in clause A.1.

An end-to-end light source or power meter test should be performed and the results should be recorded and presented as shown in clause A.2. The final test should be performed in accordance with annex B. Only a calibrated OTDR should be acceptable.



## Annex A

(informative)

### Summary tables

#### A.1 Sample of splice loss summary table

Line : Station A - B                      Fibre type: G652

Cable type: OPGW                      Refractive index: 1,468

End 1: Station A                      Helix factor: 9 %

End 2: Station B

Wavelength: 1 550 nm

	Tested from	Total length	Joint 1 distance	Joint 3 distance	Joint 9 distance	Joint 11 distance
	End 1	0	1 926	5 730	16 686	20 632
	End 2	21 144	19 218	15 414	4 458	506

Fibre No.	Tested from	Total loss	Joint 1 loss	Joint 3 loss	Joint 9 loss	Joint 11 loss
1	End 1	5,11	0,11	0,00	0,00	0,00
1	End 2	5,324	0,06	0,12	0,00	0,00
1	Average	5,21	0,09	0,06	0,00	0,00
2	End 1	5,43	0,00	0,23*	0,00	0,00
2	End 2	5,21	0,00	-0,10*	0,00	0,00
2	Average	5,32	0,00	0,07	0,00	0,00
:	:	:	:	:	:	:
11	End 1	5,41	0,00	-0,07*	0,06	0,11
11	End 2	4,90	0,00	0,09*	0,00	0,11
11	Average	5,15	0,00	0,08	0,03	0,11
12	End 1	5,02	0,09	0,00	0,05	0,06
12	End 2	5,58	0,11	0,17*	0,00	0,00
12	Splice loss	5,30	0,11	0,09	0,03	0,03

Mean loss	Worst splice loss
0,04	0,09
0,02	0,07
:	:
0,05	0,11
0,06	0,10

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

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

The above table is shortened for the sake of brevity.

NOTE The above table is not intended to represent real values. It is for illustrative purposes **only**.

**Annex A**  
(concluded)**A.2 Sample of power source and light meter summary table****Line :** Station A - B**Cable type:** OPGW**End 1:** Station A**End 2:** Station B**Line length:** 21 km**Wavelength:** 1 550 nm**Reference:** -7,3 dB

<b>Fibre no.</b>	<b>Tested from</b>	<b>dB/km</b>	<b>Receive level dB/km</b>	<b>Loss dB</b>
1	End 1	0,24	-12,4	5,1
1	End 2	0,25	-12,7	5,3
2	End 1	0,26	-12,5	5,4
2	End 2	0,25	-12,3	5,2
3	End 1	0,25	-12,8	5,3
etc.				

NOTE The above table is shortened for the sake of brevity.

## Annex B

(informative)

### Acceptance procedure for optical fibre systems

#### B.1 Scope

This procedure covers the testing of fibre optic cable systems. These systems may consist of OPGW, ADSS, externally attached cable, duct cabling or a combination of the aforementioned.

#### B.2 Splice acceptance procedure

All joints should be of the fusion type and should be to the following standard in table B.1 or otherwise agreed between the customer and contractor.

NOTE Of more significance to the operation of the total system is the mean splice loss value. On very short fibre links, a higher mean value will be acceptable.

**Table B.1 — Splice loss**

1	2	3
Splice loss <sup>a</sup>	Single mode fibre	Multimode fibre
Maximum	≤ 0,1 dB	≤ 0,15 dB
Mean <sup>b</sup>	≤ 0,075 dB	≤ 0,1 dB
<sup>a</sup> The splice loss is the numerical average of an individual splice as measured in both directions with an OTDR. <sup>b</sup> The mean splice loss is the sum of all individual splice losses on a particular fibre divided by the total number of splices on that fibre.		

Any joint which has a measured loss higher than the specified value should be broken and redone.

If, after attempting to re-splice for a total of 3 times, the individual splice loss is still above the specified limit, the splice can be accepted provided that the mean splice loss is within the specified limits. A note to this effect must be made in the relevant test documentation

#### B.3 Fibre optic testing procedure

**B.3.1** The aim of these tests is to establish whether the fibre optic installation is acceptable or not.

After installation the complete system should be tested from end to end. The customer should be given the opportunity to carry out final acceptance testing in conjunction with the supplier's staff. The customer's presence should not relieve the supplier of his responsibility for the satisfactory performance of the equipment during site testing and thereafter through to the end of the warranty period.

**B.3.2** Carry out the following tests for cable systems with one or more 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.

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).

## Annex B

(continued)

Use the correct effective group refractive index as provided by the optical fibre manufacturer. Indicate this on the splice summary table given in clause A.1.

Set the helix factor stipulated by the supplier and indicate it on the splice summary table (see clause A.1).

Indicate on the splice summary table (see clause A.1) the back scatter coefficient for each wavelength as supplied by the cable manufacturer.

Indicate acquisition time settings on the splice summary table (see clause A.1).

**B.3.3** For normal attenuation measurement, the wavelength tolerance should be within  $\pm 20$  nm of the normal central wavelength, for example 1 310 nm or 1 550 nm. For line lengths up to 50 km attenuation measurements should include both wavelengths. For lines in excess of 50 km wavelength tests at 1 550 nm need only be done.

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

All measurements should be bidirectional.

**B.3.4** OTDR traces should provide 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 should be done in both directions at both 1 310 nm and 1 550 nm windows. Test results should also be provided on a data disc.

**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.

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.

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

Adhere to the OTDR maximum pulse widths as given in table B.2.

**Table B.2 — OTDR maximum pulse widths**

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

Insert the following information on each OTDR trace:

a) date;

## **Annex B**

(concluded)

- b) fibre optic cable description;
- c) fibre number;
- d) the end from which the test is being performed;
- e) index of refraction;
- f) helix factor; and
- g) Rayleigh backscatter coefficient.

**B.3.5** Ensure that the following data are available on request:

- a) OTDR instrument (including make, model and manuals and also a copy of the trace analysis software);
- b) calibration data (central wavelength(s) as verified by an NCS-approved facility);
- c) launch conditions; and
- d) splice machine (including make, model and manuals).

Summarize all the information in table form as shown in the example in clause A.1.

Measure the total end-to-end loss (patch panel enclosure to patch panel enclosure) from both ends using a light source and an optical power meter. Results for both 1 310 nm and 1 550 nm windows are required. Provide details of the instrumentation and launch conditions used in the documentation in clause B.4.

Commissioning should be done in close co-operation with, and to the full satisfaction of the customer.

The customer reserves the right to have several technicians actively participate in the fibre section link tests with the objective of them gaining intimate knowledge of the testing procedures.

## **B.4 Documentation**

**B.4.1** The supplier should supply documentation as specified in the contract.

**B.4.2** All documentation called for should be provided in hard-cover ring files which comply with the requirements in B.4.3 to B.4.7 inclusive.

**B.4.3** Documentation should be supplied in English.

**B.4.4** Documentation should be supplied on A4 paper.

**B.4.5** The hard-cover ring files should be of a construction that can open flat on any page.

**B.4.6** Any drawings and descriptions included should conform to the A4 series (295 mm x 220 mm). Larger drawings should be folded in a single panel along the 200 mm axis of the standard A4 size.

**B.4.7** Different sections of the documentation should be separated by means of thumb-tag separators.

**B.4.8** The documentation should include the following:

- a) an index;
- b) test certificates for site tests of fibre before installation;
- c) details of fibre numbering and colour coding;
- d) a system diagram that shows joint locations and distances between joints;
- e) a table of joint losses and distances similar to the example in annex A;
- f) OTDR traces for each fibre in both directions and at both 1 310 nm and 1 550 nm windows (paper copy and electronic copy on disc); and
- g) a table of end-to-end attenuation using the light source or power meter technique similar to the example given in clause A.2.

### Annex C

(informative)

#### Typical installation drawings and fittings

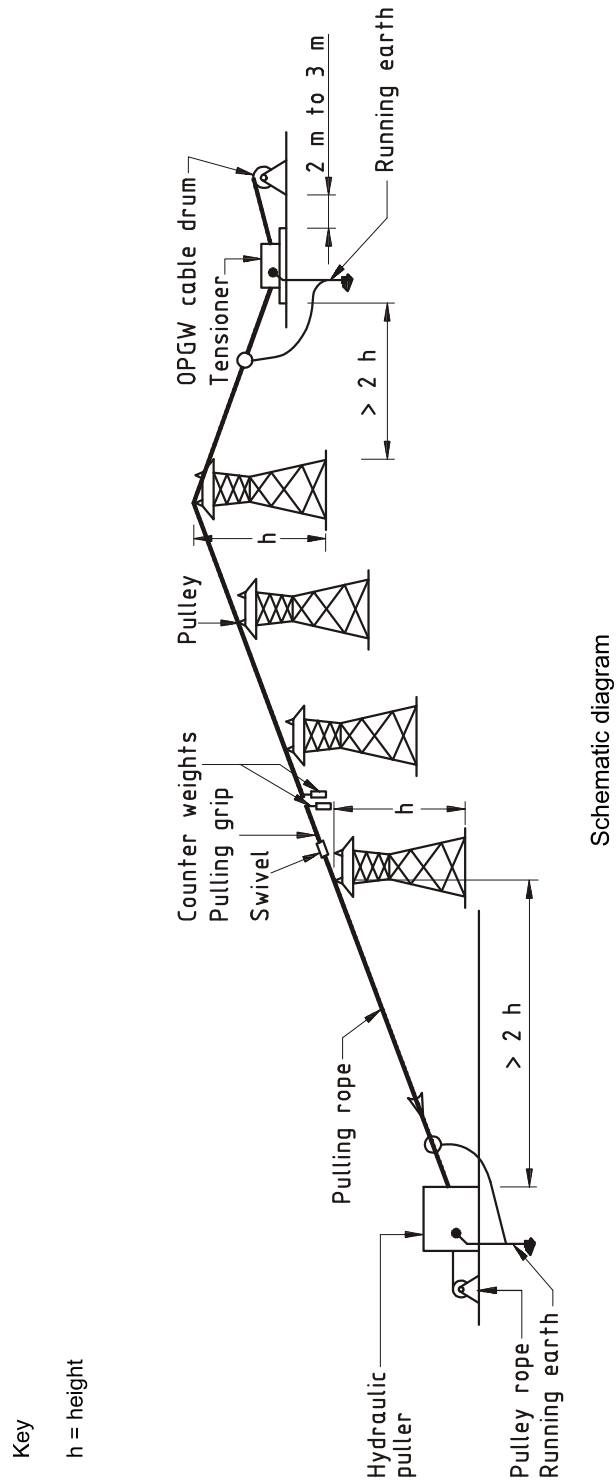
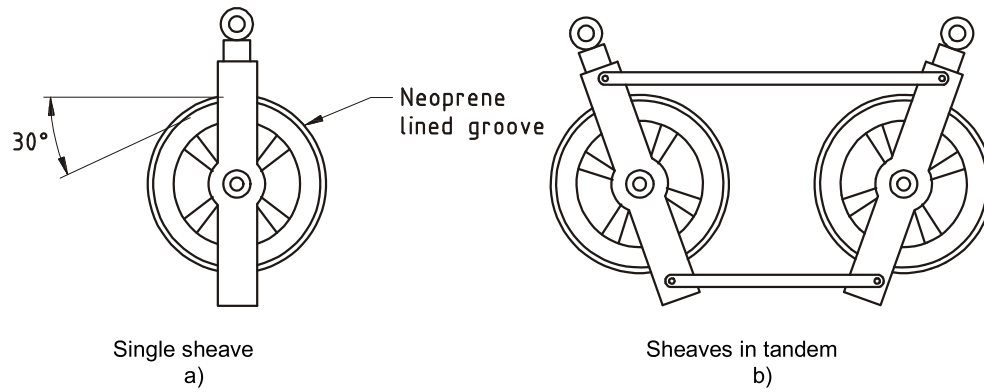


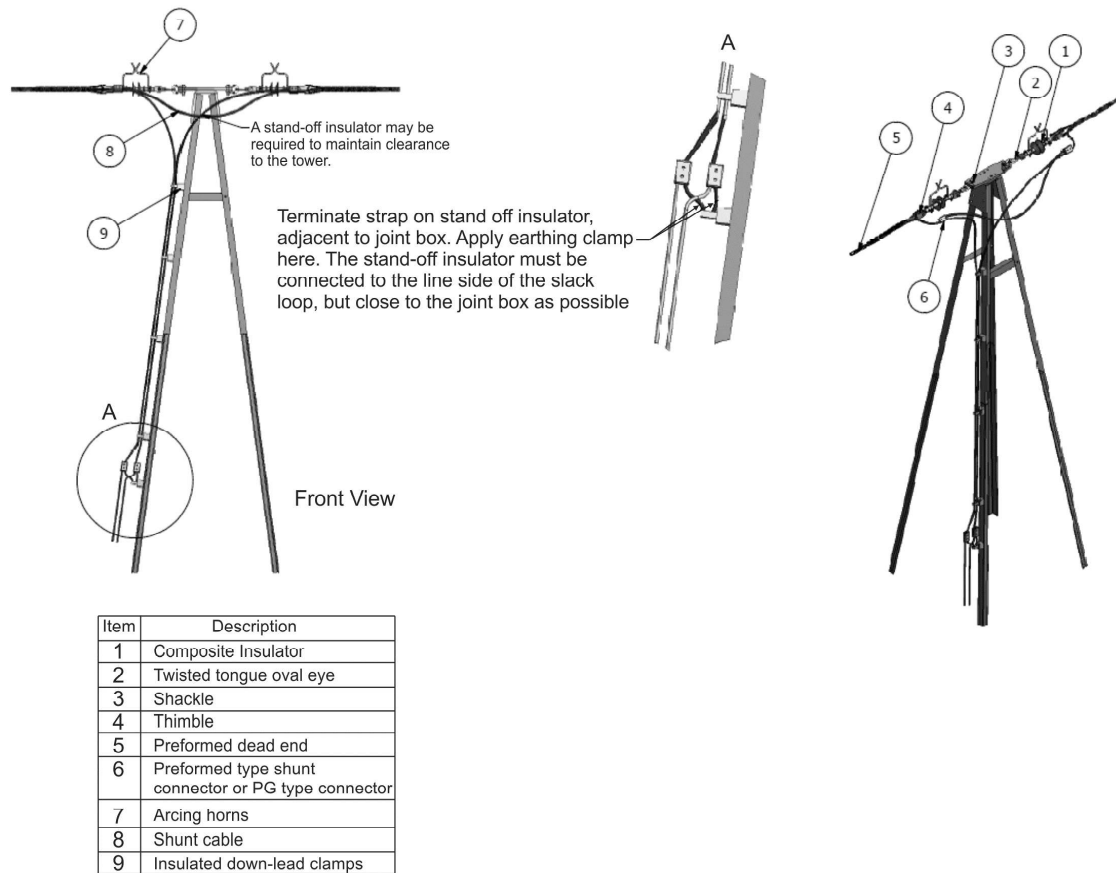
Figure C.1 — Standard method of stringing

**Annex C**  
(continued)



**Figure C.2 — Sheave arrangement**





**Figure C.3 — OPGW insulated strain assembly at splicing tower**

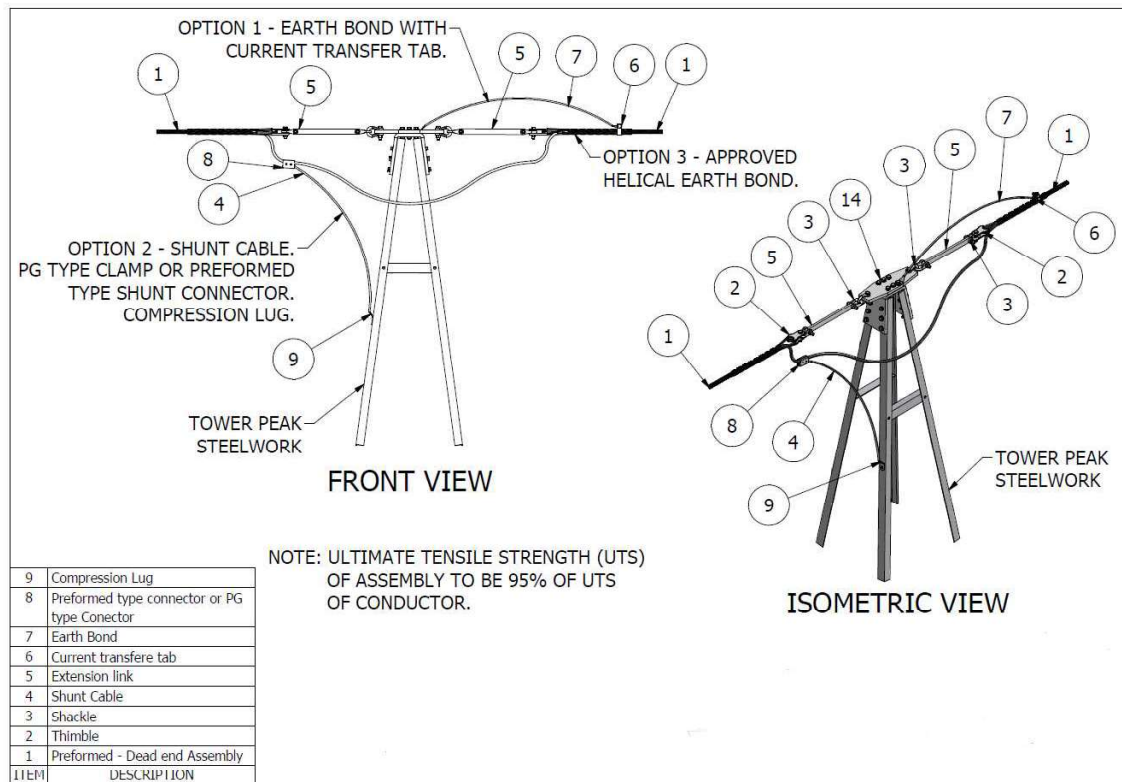
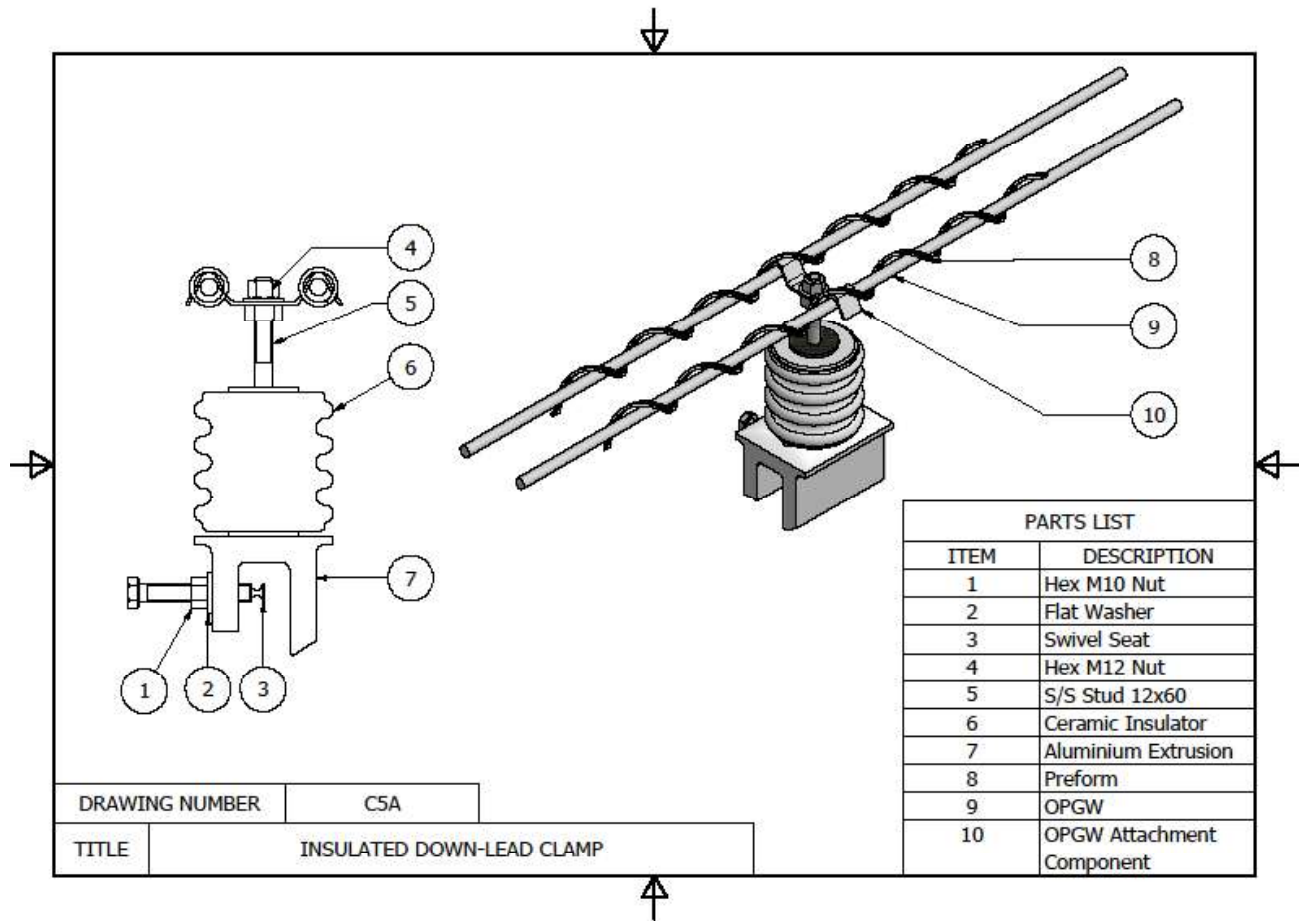


Figure C.4 — OPGW non-insulated strain assembly at splicing tower

**Annex C**  
(continued)

Dimensions in millimetres

**Figure C.5A — Typical OPGW insulated down-lead clamp**

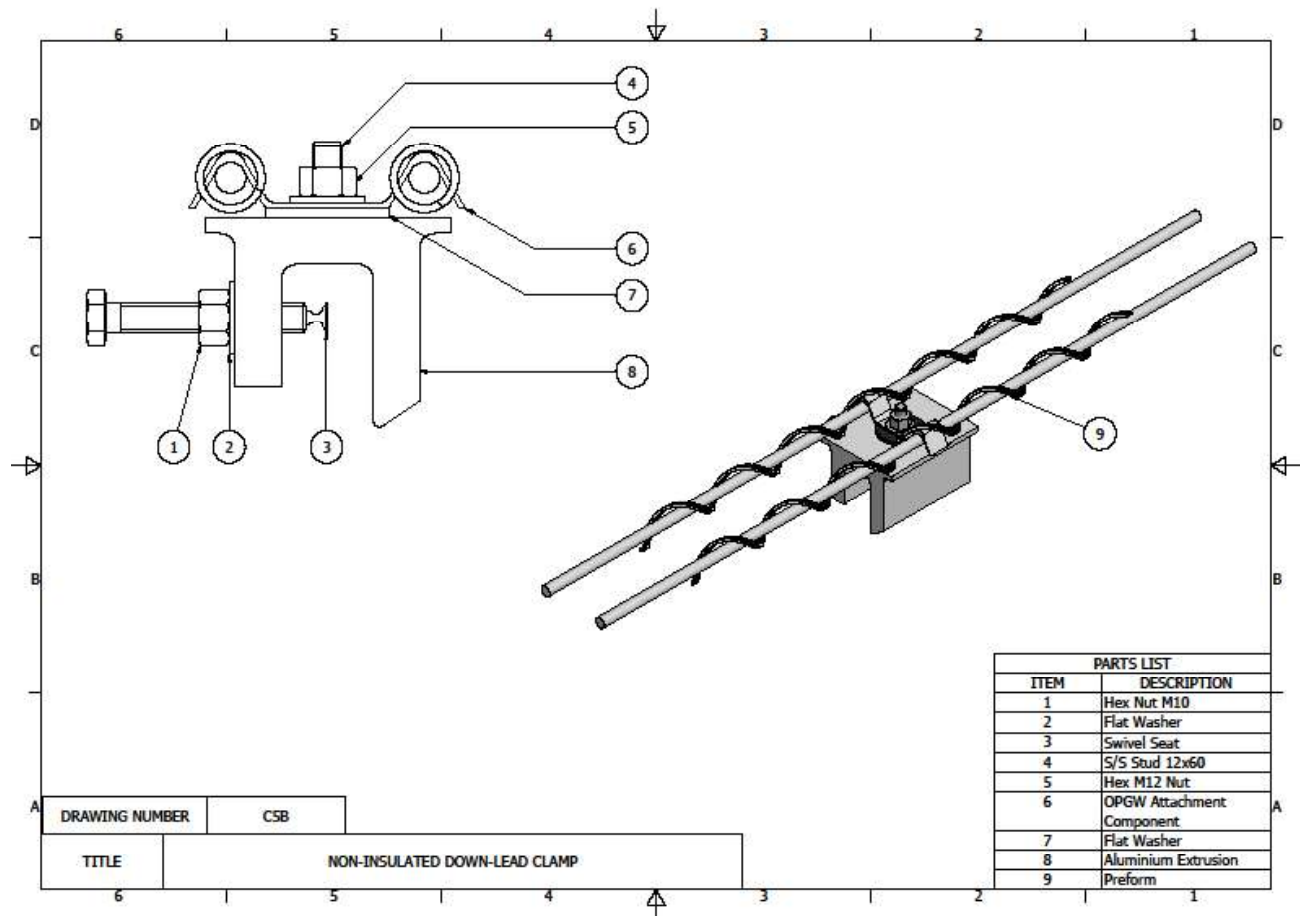
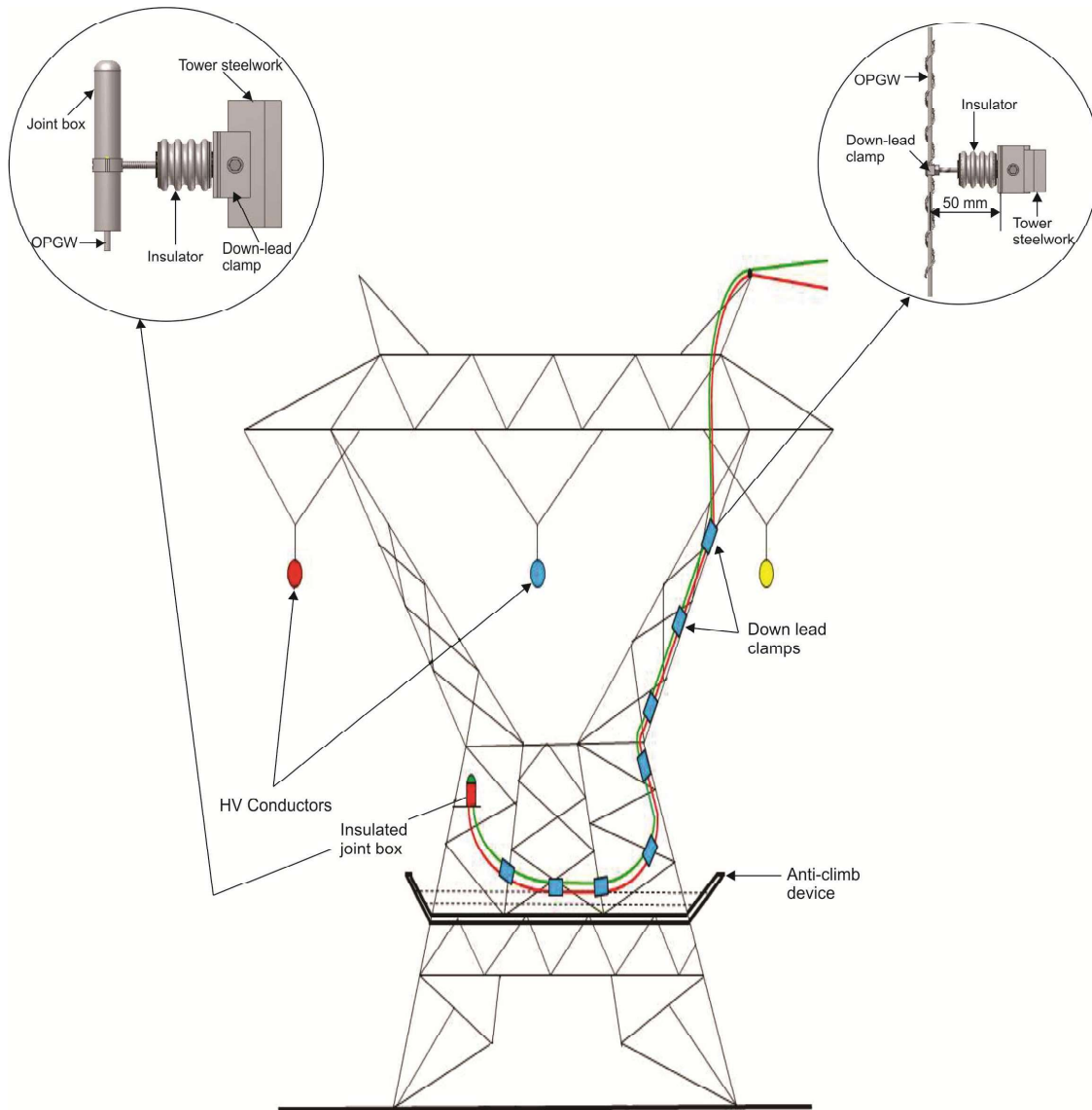


Figure C.5B — Typical OPGW non-insulated down-lead clamp

**Annex C**  
(continued)**Figure C.6 — Typical installation at insulated splicing tower**

### Annex C

(continued)

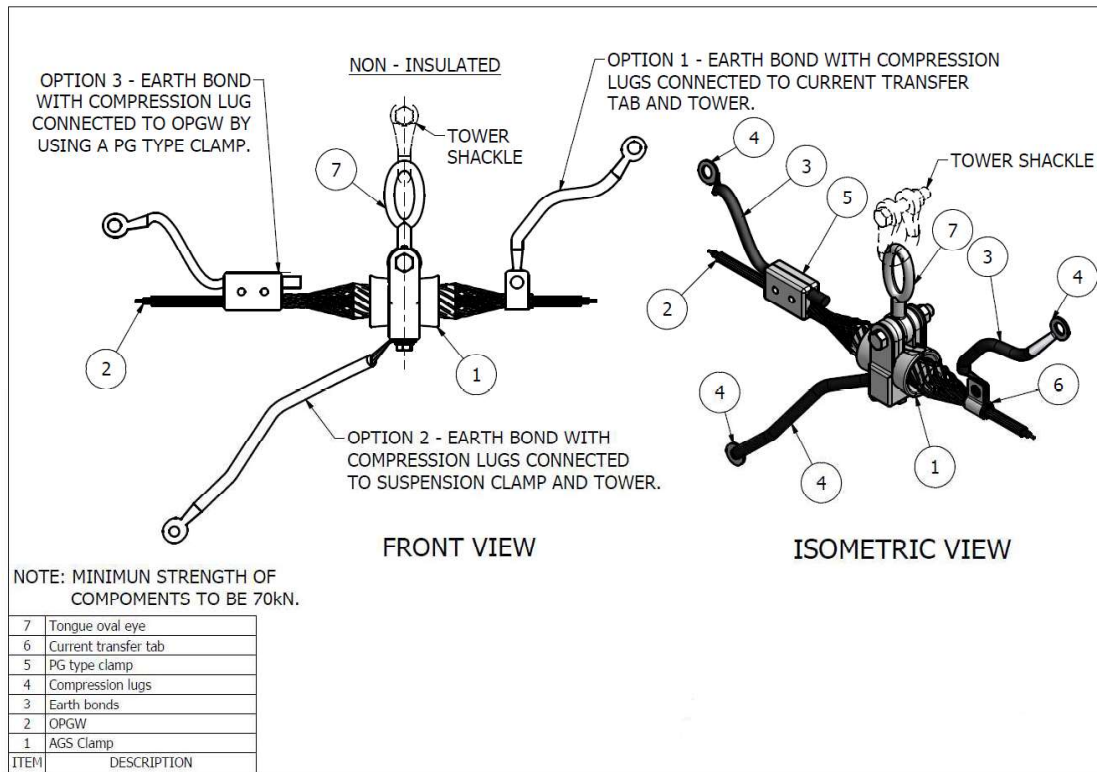


Figure C.7 — Non- insulated OPGW standard suspension assembly

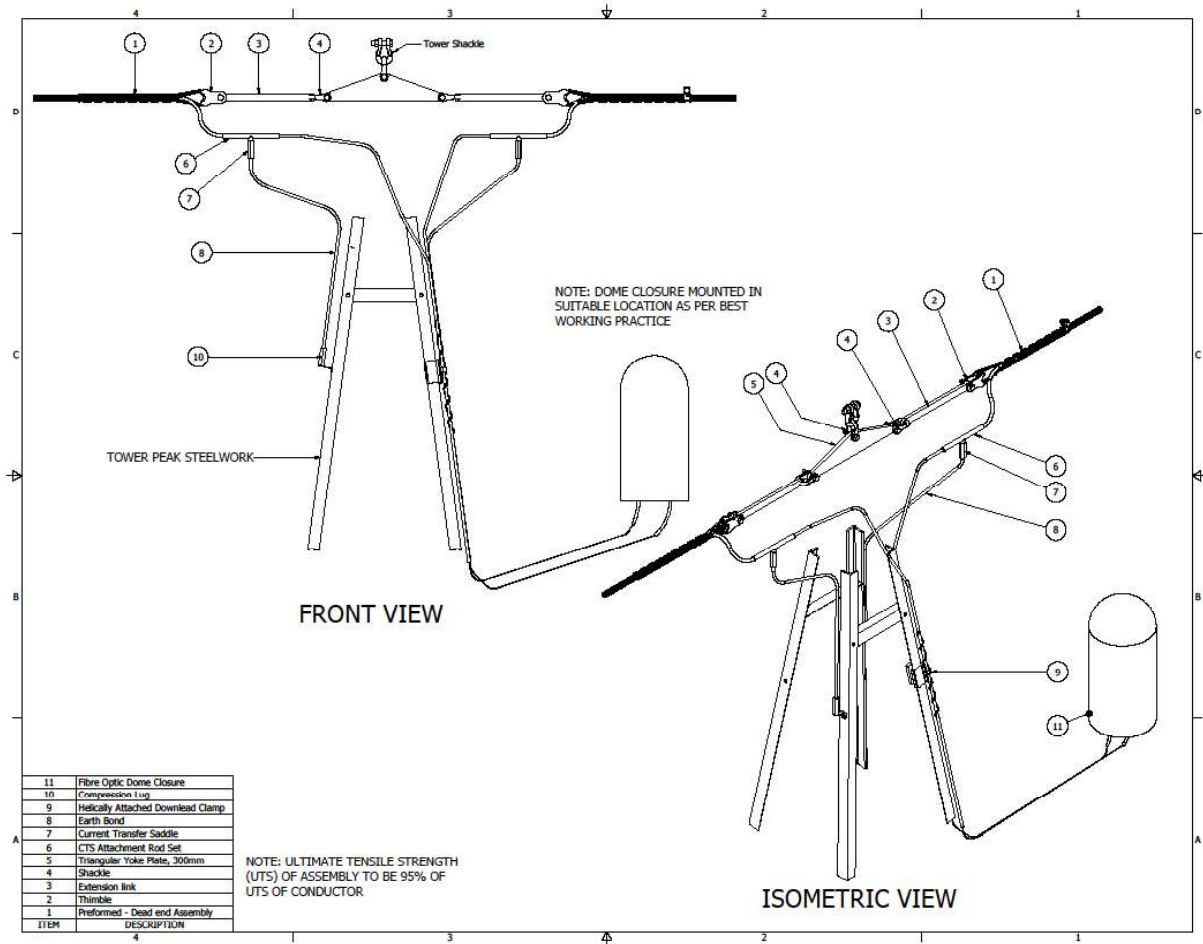


Figure C.8A — Non insulated suspension assembly at joint box

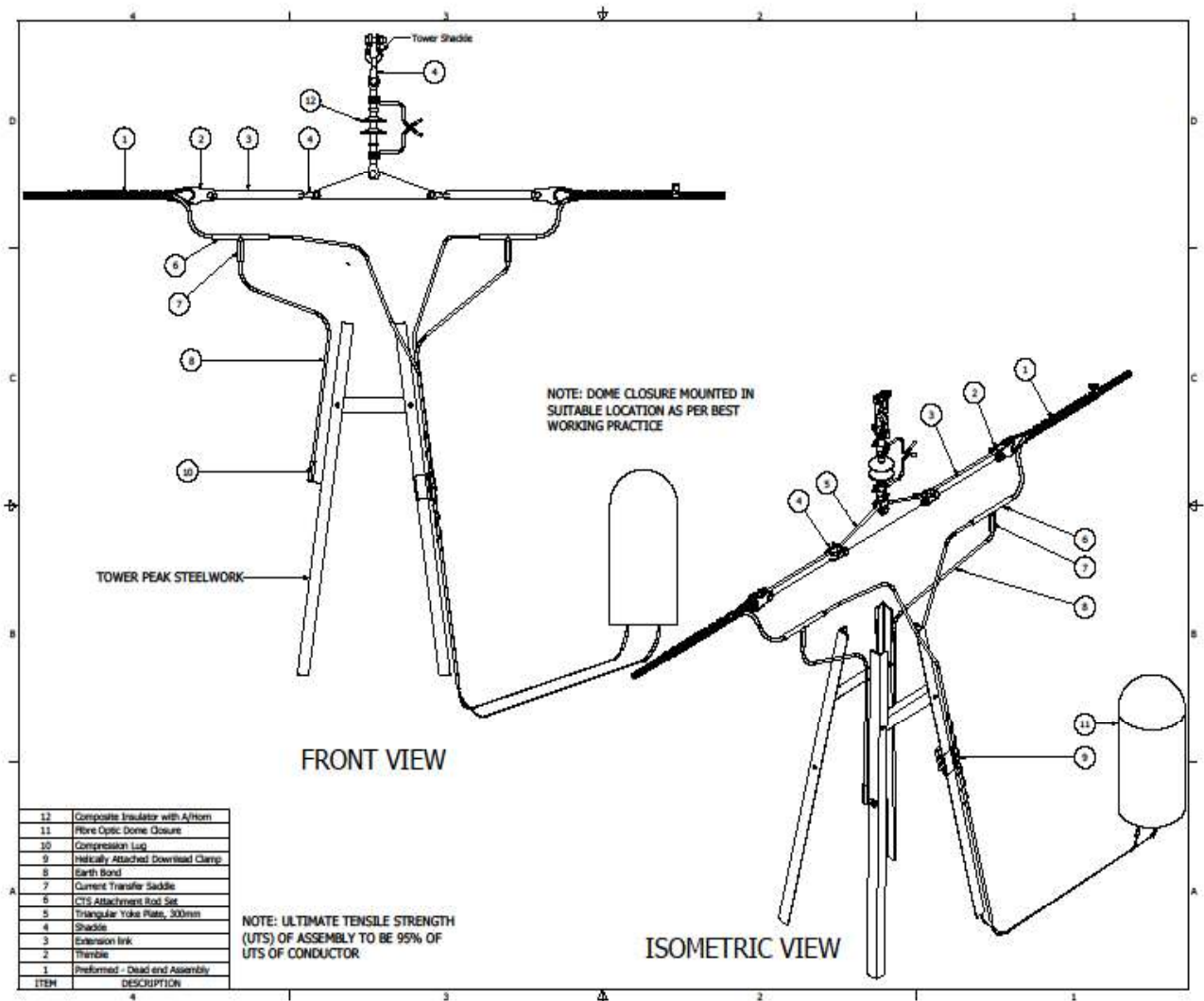
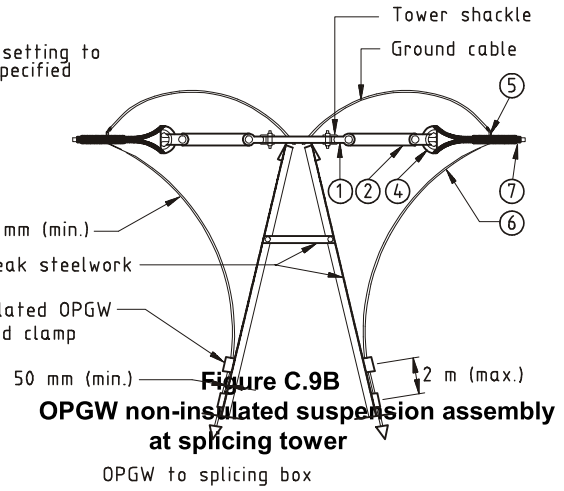
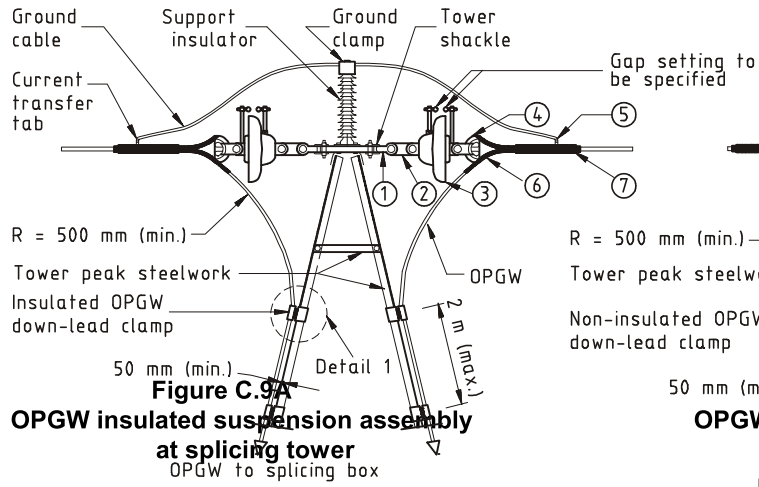


Figure C.8B — Insulated suspension assembly at joint box





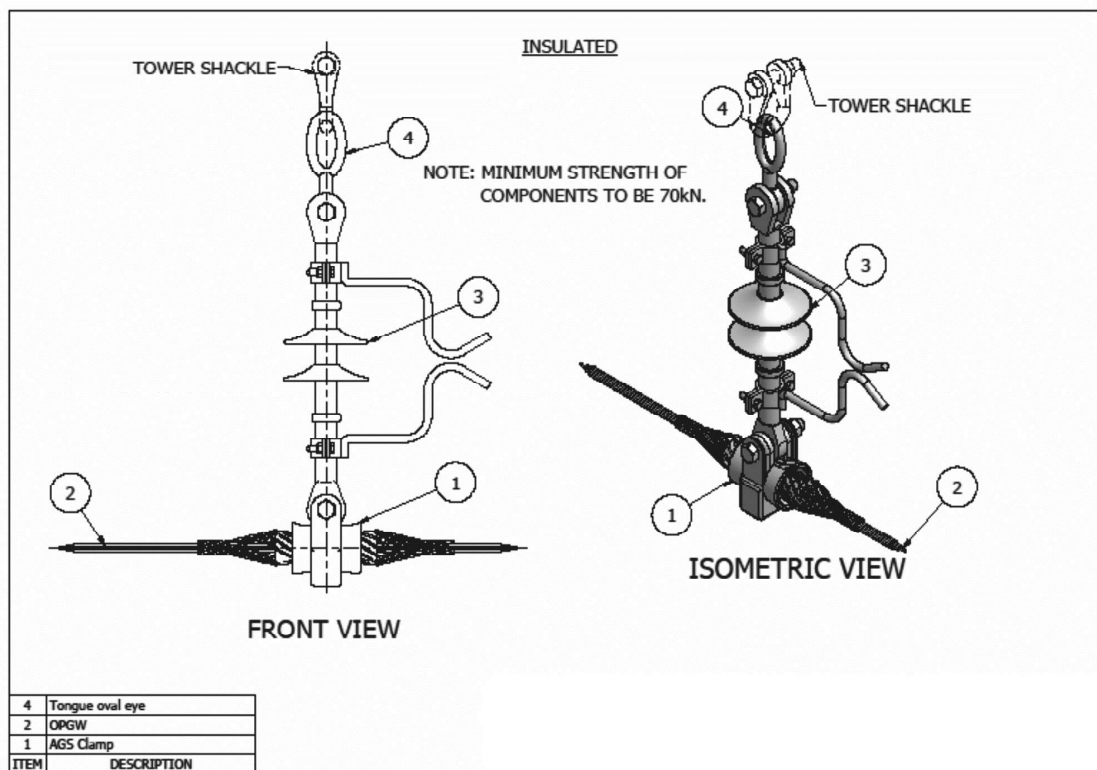
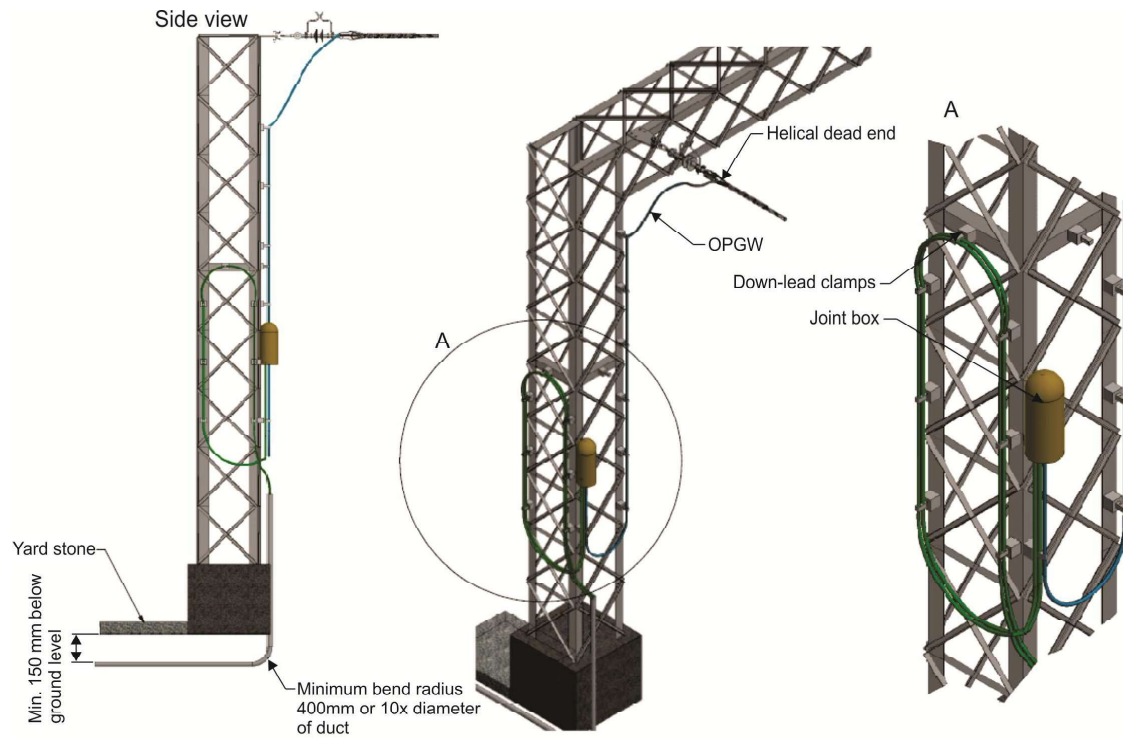


Figure C.10 — Insulated OPGW standard suspension assembly

**Annex C**  
(continued)**Figure C.11 — Termination and earthing arrangement at gantry**

Annex C  
(concluded)

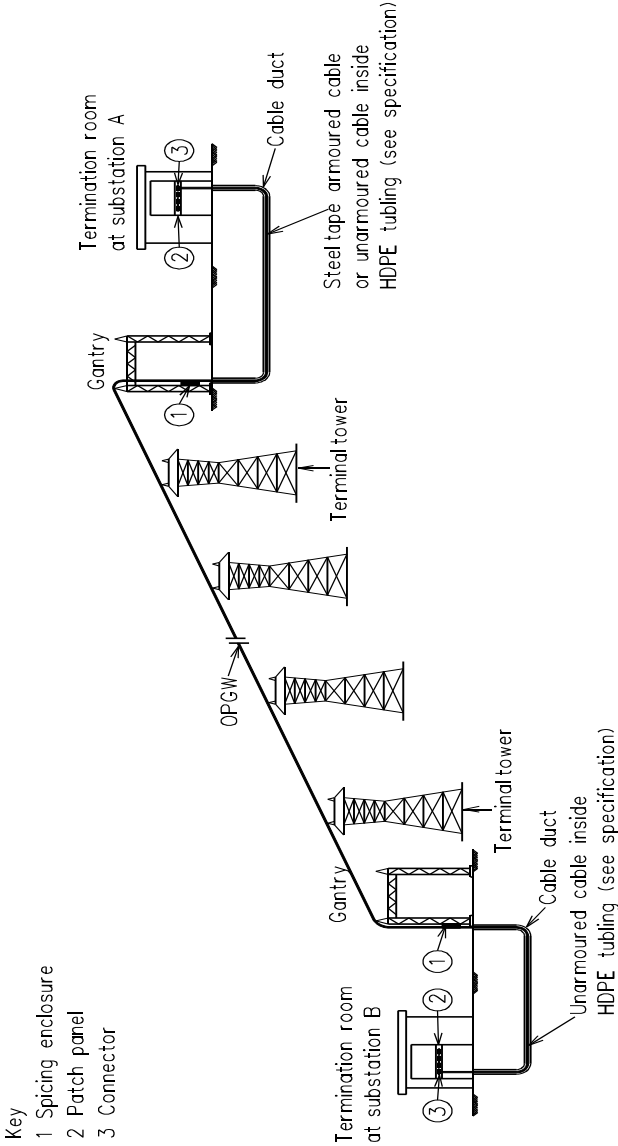


Figure C.12 — Completing OPGW installation to the termination room

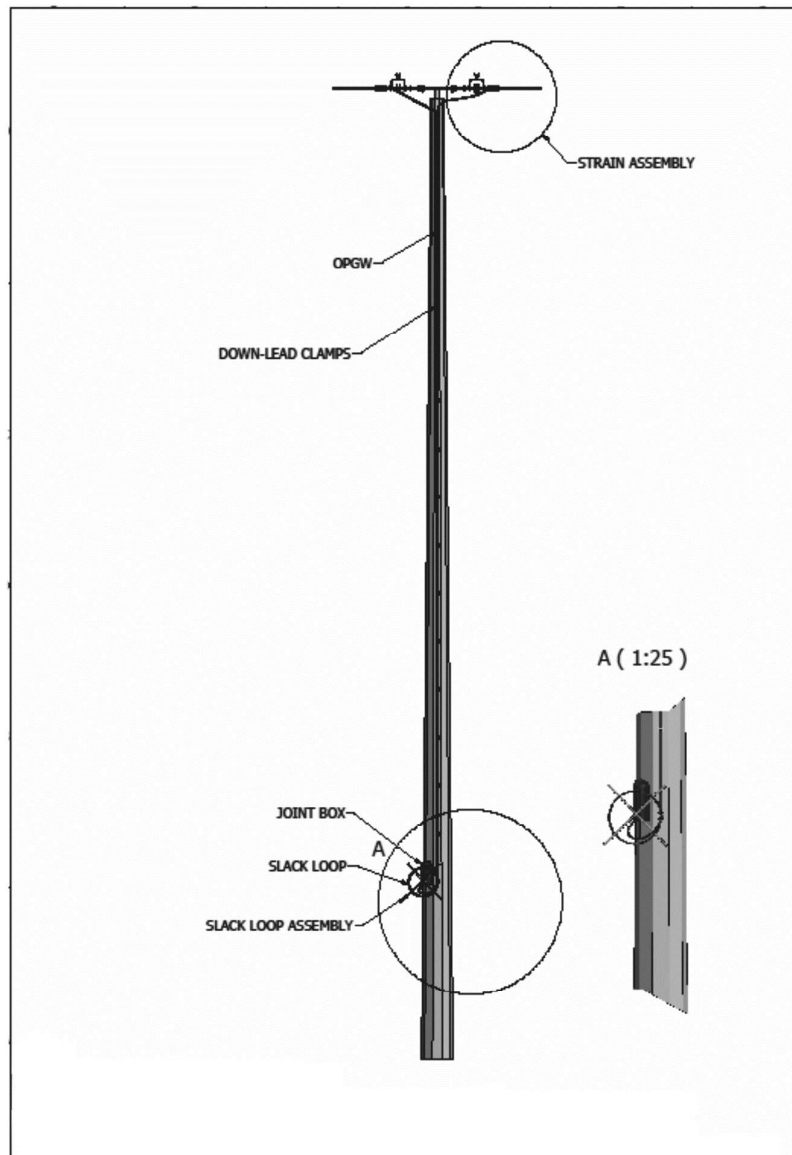


Figure C.13 — Joint enclosure with slack bracket for steel pole

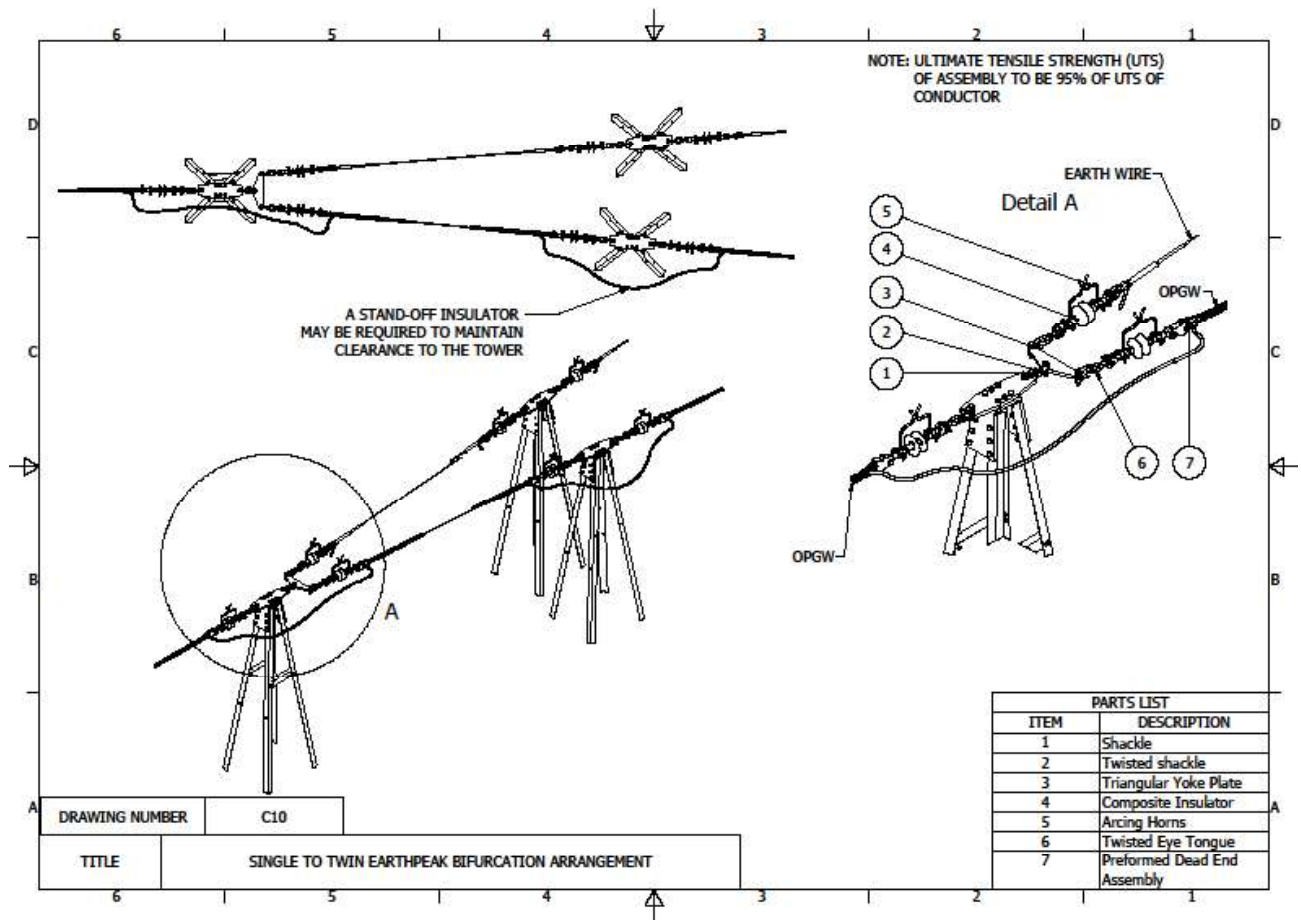


Figure C.14 — Single to twin earth peak bifurcation arrangement

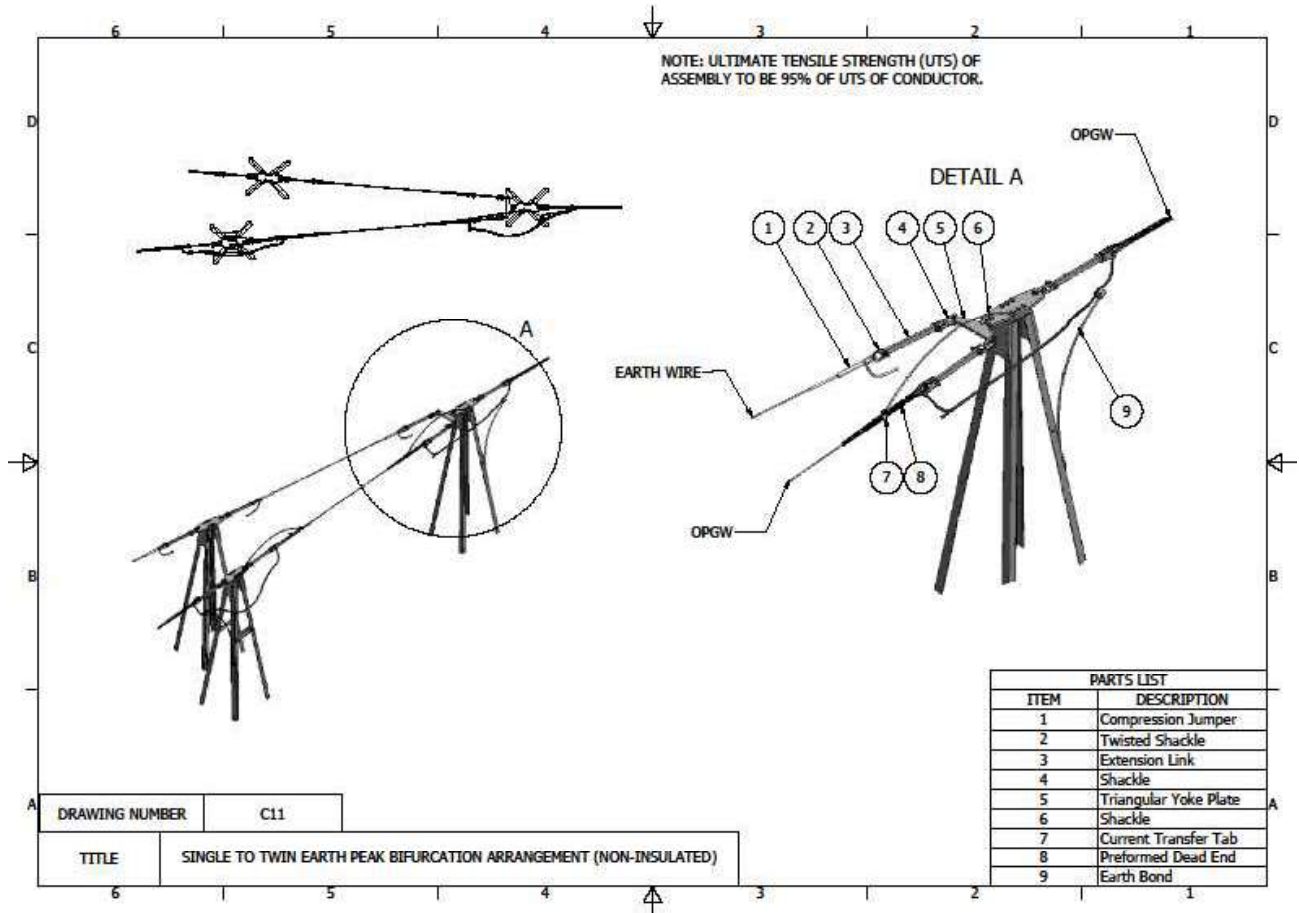


Figure C.15 — Single to twin earth peak bifurcation arrangement (non-insulated)

## **Bibliography**

SANS 9001/ISO 9001:2000, *Quality management systems – Requirements.*