Eskom	**Standard**	Transmission

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Content

Tables

1. Introduction

This document is prepared by Eskom Holdings SOC Limited and describes requirements to be met by manufacturers of overhead line hardware in conjunction with relevant international requirements.

2. Supporting clauses

2.1 Scope

This specification covers the technical requirements for the design, manufacture, testing and delivery of suspension and strain assemblies, or of individual items not covered in the international specifications. The assemblies and items shall be used on Eskom's High Voltage overhead power transmission and distribution systems.

2.1.1 Purpose

The following specification is to provide technical guidance and requirements to manufacturers of various types of hardware assemblies and components in order to maintain uniformity and best practicing.

2.1.2 Applicability

This standard is applicable to Eskom Holdings SOC Limited its divisions Eskom Transmission and Distribution.

2.2 Normative/informative references

The following documents contain provisions that, through reference in the text, constitute requirements of this standard. At the time of publication, the edition indicated was valid. All controlled documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the documents listed below. Information on currently valid national and international standards and specifications can be obtained from the Information Centre and Eskom Documentation Centre at Megawatt Park.

Except where otherwise stated, all items of hardware shall comply with this specification and the latest revisions at the time of tender of the following specifications:

2.2.1 Normative

[1] SANS IEC 61284:1997-09, Overhead lines- Requirements and tests for fittings.

[2] SANS 60120:1984 -01, Dimensions of ball and socket couplings of string insulator units.

[3] SANS 60372:1984 –01, Locking devices for ball and socket couplings of string insulator units: Dimensions and tests.

[4] SANS 60471:1977, Dimension of clevis and tongue couplings of string insulator units.

[5] ASTM A 370:1997, Standards, methods and definitions for mechanical testing of steel products.

[6] ASTM E 3:1985, Preparation of Metallographic Specimens

[7] ASTM E 92:1982, Standard test method for Vickers Hardness of Metallic Materials.

[8] ASTM E 384:1999, Test for Microhardness of Materials

[9] ASTM E 709:2008, Recommended practice for magnetic particle examination.

[10] BS 970 Part I:1996, Specification for wrought steels for mechanical and allied engineering purposes: General inspection and testing procedures and specific requirements for carbon, carbon manganese, alloy and stainless steels.

[11] BS EN 1559-1:1997, Founding- Technical conditions of delivery Part 1.

[12] BS EN 1676 : 1997, Aluminium and aluminium alloys. Alloyed ingots for remelting. Specifications

[13] BS EN 1706:1998, Aluminium and Aluminium alloys- Castings- chemical composition and mechanical properties partially supersedes BS 1490- 1988.

[14] BS EN 1559- 4: 1999, Technical conditions of delivery –Part 4. Additional requirements for Aluminium Alloys castings together with BS EN 1706- 1998, BS EN 1676: 1997 and BS EN 1559-1: 1997.

[15] BS EN 10160:1999, Methods for ultrasonic testing and specifying quality grades of ferritic steel plate.

[16] BS3288 Part 2:1990, Insulator and conductor fittings for overhead power lines, Part 2- Specification for a range of fittings.

[17] SANS 1700-1-1: 2010, series 1, Fasterners

[18] SANS 1190: 2011,Malleable Iron castings.

[19] ISO 1461:2009,Hot-dip galvanized coatings on fabricated iron and steel articles- Specification and test methods.

[20] EVS 003:1988, Qualification, certification and Eskom approval of non-destructive examination personnel on all Eskom plant.

[21] D Warren: "Hydrogen Effects on Steel", Materials Performance January 1987, p 38-48.

[22] IEC 61854: 1998-09, Overhead lines: Requirements and tests for spacers.

[23] IEC 61897: 1998, Overhead lines: Requirements and tests for Stockbridge type Aeolian vibration dampers.

[24] ISO 9001, Quality Management Systems.

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

Definition	Description
Load Bearing Component	Any component subject to mechanical stress or a combination of stresses, as part of its function or geometry.
Final Product	A final product is where all manufacturing and shop operations have been completed and the product is ready for in-service use.
Type Tests	The type test shall verify the main characteristics of the item. This test shall be done once and repeated only when the design, the material, method of manufacture (heat treatment, protective coating application or any other process that could affect the end product) or source of supply of the components (parts used in a final product) is changed.
Sample test	The purpose of this test is twofold. Firstly, to determine the material mechanical properties after final manufacturing (shop operations) have been completed. Secondly to determine the final product's compliance to requirements.
Production Routine Test	Routine tests are intended to ensure defect free components by means of non-destructive testing.

Definition	Description
Test bar	In the case where the final product is of such size and geometry that test specimens according to ASTM 370 cannot be cut or machined from it or from the critical or minimum diameter/wall thickness sections of the item, then a test bar shall be prepared. A test bar shall undergo the same manufacturing process (including heat treatment and coating application such as galvanizing) as the final product. The test bar shall be of such a size that it represents the critical diameter/wall thickness of the item, and at least 3 tensile and /or 3 Charpy impact test specimens can be machined from it. A test bar shall be prepared for every batch manufactured.

2.3.2 Disclosure classification

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

2.4 Abbreviations

None

2.5 Roles and responsibilities

Not applicable.

2.6 Process for monitoring

Not applicable.

2.7 Related/supporting documents

Not applicable.

3. Requirements

3.1 General

Nothing in this specification shall lessen the obligations of the supplier detailed in any other document forming part of a contract.

3.1.1 Workmanship

All items of hardware shall conform to requirements set out by IEC requirements and documented work methodology stipulated by the relevant product requirements. All products must have a consolidated manufacturing requirement which is prepared by the manufacturer taking into account relevant manufacturing processes.

3.1.2 Drawings

3.1.2.1 Drawings shall be supplied in accordance with the enquiry document and accepted by Eskom responsible engineer before production begins.

3.1.2.2 Tower shackles shall not be shown or included on assembly drawings, unless otherwise depicted by the applicable conceptual assembly drawing which is provided by Eskom. If tower shackles are required, they shall be shown and offered separately.

3.1.2.3 All drawings supplied by the manufacturer shall contain sufficient information to enable structural strength calculations to be made for the items of hardware.

3.1.2.4 All drawings shall clearly indicate all critical tolerances on items of hardware.

3.1.2.5 The name of the applicable transmission line shall be clearly indicated on all drawings.

3.1.2.6 All drawings shall clearly indicate material grade, heat treatment required for individual items, bolt torques and final hardness and material properties.

3.1.2.7 Before production, the successful tenderer shall supply to Eskom, a copy of the accepted final original drawing.

3.1.2.8 Any revisions to drawings of items of hardware being manufactured for and supplied to Eskom shall clearly indicate the revision number and date, and shall be submitted to Eskom for acceptance.

3.1.2.9 Manufacturers to only use individual components in assemblies that have been tested together and proves to be interactive with correct clearances and movement where required. Eskom will not take responsibility for non-compliant items on assemblies due to fitment issues after acceptance of drawings.

3.1.3 Tolerances

Dimensions of all items of hardware shall be subject to the tolerances specified in the referenced standards. Where no standard or tolerance is referenced, the fit tolerance shall be ± 2 % or within ± 0.7 mm. All tolerances shall be subject to Eskom's approval. Items of hardware found to be out of tolerance will be rejected. Where manufacturer’s tolerances are stipulated outside the Eskom requirements, reasons for these tolerances must be stipulated and accepted by Eskom before any production occurs.

3.1.4 Installation procedures

Details of installation procedures shall be supplied both with the offer and with each batch delivered. Where installation of hardware is of critical concern to the lifespan of conductor, relevant training shall be offered by the supplier.

a) The supplier shall be fully responsible for his designs and their satisfactory performance in service. Acceptance by Eskom does not relieve the supplier of responsibility for the adequacy of the design, dimensions and details.

b) Suspension and strain assemblies shall be designed such that line contact occurs between coupled components. Point contact between components shall be avoided. The method of contact shall be subject to Eskom's acceptance. For example,

- Ball fittings always mate with socket fittings.
- Tongue fittings always mate with clevis fittings
- Eye fittings always mate with shackles and not with bolts.
- Y-clevis always mates with eyes or shackles.

c) Unless otherwise stated, tower shackles will be supplied by the tower supplier, and do not form part of the suspension or strain assembly supply.

d) Preference will be given to self-grading assemblies which do not require additional corona control devices. This will be by Eskom acceptance.

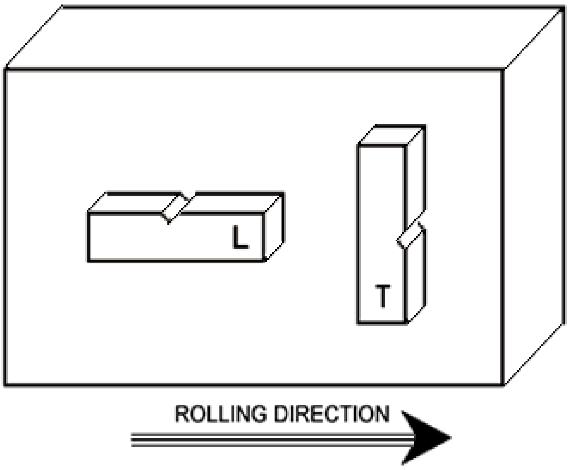
e) No castings shall be used for load bearing components except in the case where aluminium or alumninium alloy is the material used in suspension clamps.

3.2 Material

a) The material selected for each component shall be suitable to meet service life requirements and shall comply to Clause 4.1.2.1 SANS IEC 61284.

b) The flow stress of the chosen ferrous materials in the final product shall be less than 1 000 MPa. Flow stress = ½ (Yield + UTS). Ultimate Tensile Strength (UTS) of final product material are not to exceed 1 000 MPa. This requirement is stipulated to minimise or limit the possibility of hydrogen pick-up (during manufacturing or in-service conditions) for material susceptible to hydrogen absorption.

c) All samples of ferrous material taken from the final product and/or test bar shall have a minimum Charpy V-notch impact energy of 27 Joules at 0°C. Charpy V-notch testing shall be conducted in accordance with ASTM E23 - 07ae1 Standard Test Methods for Notched Bar Impact Testing of Metallic Materials. For components that are manufactured from rolled or extruded materials, charpy V-notched specimens shall be taken in the longitudinal rolling direction. Figure 1 below shows the direction of the specimen in relation to the rolling direction of the grain.



d) Ductility of all ferrous material at room temperature shall be sufficient to provide a minimum elongation in a gauge length of 5.65√So, including the fracture, of 16 percent. (So = cross section area of the test specimen).

e) All stainless steel components shall be of a grade, condition and design which will not enhance stress corrosion cracking and shall be subject to Eskom's acceptance.

f) Where aluminium is used it shall be in accordance with BS EN 1559-1:1997, BS EN 1676 : 1997,BS EN 1706:1998, BS EN 1559- 4: 1999. The choice of alloy, its mechanical properties and proposed method of manufacture shall be subject to Eskom's approval and comply to Clause 4.1.2.2, SANS IEC 61284.

g) To enhance material selection with regard to fatigue properties, the following table lists the possible cyclic loads and impact loads the components may experience in 50 years.

Table 1: Fatigue and impact loads

		TENSION (PERCENT OF MINIMUM FAILING LOAD)	
CASE	**CYCLES**	**MIN (Lower Limit)**	**MAX (Upper Limit)**
1 (fatigue)	300 000	20	25
2 (fatigue)	100 000	20	30
3 (Impact)	1	20	35
4 (Impact)	1 (impact load 0,25 sec rise time)	20	90

h) Any material covered by BS 970 (or equivalent specification) which has received heat treatment shall be shot blasted (wheel-abrated) to SA 2.5, (except for threaded items), prior to galvanizing. Rinsing, in inhibited hydrochloric or sulphuric acid, prior to fluxing and immersion in molten zinc shall be limited to a minimum period in order to avoid hydrogen absorption.

3.3 Suspension assembly

3.3.1 General

a) V-string assembly

- The suspension assembly consists of suspension clamp sub-assemblies, suspension yokes, socket clevises, ball-eye links, extension straps and shackles. Provision shall be made to enable live-line maintenance of assemblies.
- For bundle conductor assemblies the centre of gravity shall be at or below the apex of the insulator string V.

b) I-string assembly

- The suspension assembly in general consists of suspension clamp sub-assemblies, suspension yokes, socket clevis, ball-eye link and shackles. Provision shall be made to enable live-line maintenance of assemblies.

3.3.2 Suspension Clamp sub-assembly

a) The suspension clamp shall be designed to accommodate the required conductor or conductor and armour rods when called for in an enquiry document.

b) All suspension clamps shall be free-swinging with the following minimum articulation unless otherwise agreed by Eskom:

- Each clamp shall be capable of rocking 30° either side from the "at rest" position.
- Each clamp shall be able to twist 5° either side from the "at rest" position.
- Each clamp on the V-string assembly shall be able to swing 45° before contacting any other component of the assembly.
- Each clamp on the I-string assembly shall be able to swing 15° before contacting any other component of the assembly.
- Provision shall be made for maximum longitudinal movement of any one sub-conductor.

3.3.3 Requirements for live-line maintenance

a) The suspension assemblies shall be designed to allow maintenance under live conditions using the bare hand technique. Where yokes are used, maintenance procedures will involve collapsing the insulator string by lifting the yoke vertically from above or along the centre line of the string.

b) When required, suspension yokes shall be suitably designed to accept a live-line saddle yoke. The saddle yoke to suspension yoke connection shall be capable of accepting the insulator load during live-line maintenance. The cross-section of the saddle will be 75 mm wide and 100 mm deep.

c) All designs of suspension yokes for live-line maintenance shall be subject to Eskom's approval.

3.4 Strain assembly

3.4.1 General

a) The strain assembly, in general, consists of the necessary components to attach conductor compression fittings to strings of insulators and to connect the insulator strings to the tower shackle(s) normally attached the tower attachment plate. The use of wedge type strain clamps is preferred.

b) Components on the conductor end of the insulators consist of shackles, clevis tongues, sag adjusters and live-line socket clevises. Strain yokes, spreader assemblies and grading rings shall be included when required. Components on the tower end of the insulators shall consist of live-line ball -clevis links, shackles and chain link. Multiple strain yokes shall be included when required. The design of multiple strain yokes connecting the insulator strings to the single tower attachment shall be subject to Eskom approval. Any additional components shall be subject to Eskom's approval.

c) In case where double attachment of the hardware is made to the tower landing plates, extension links must be designed to cater for the full range of Line deviation angle for that particular tower.

d) Strain assemblies must be designed to cater for appropriate clearances between the parallel insulators or insulators with corona rings. Designers should have the insulator dimensions at hand when designing the string.

3.4.2 Requirements for live-line maintenance

a) The strain assembly shall be designed to allow insulator replacement under live conditions. Maintenance procedures will involve strain poles and an insulated boom and cradle.

b) When specified in an enquiry document a live-line socket clevis shall be installed at the ball-end of each insulator string while the socket end of the insulator string shall be connected to a live-line ball clevis link.

c) The design of the live-line socket clevis and ball clevis links shall be subject to Eskom's approval.

3.5 Rigging holes

a) A minimum of one rigging hole is required on the upper centre of V-string suspension yokes. Additional holes may be required to support the stringing block which will support the conductors and a single pulling line in a horizontal plane.

b) A rigging hole in strain yokes shall be provided to allow for the attachment of the strain assembly to the tower shackle.

c) Number, diameter and location of rigging holes shall be subject to Eskom's approval.

3.6 Grading rings

a) Grading rings, when required, shall grade the live end of the complete hardware assembly to within acceptable limits when required. See clause 5.1.5

b) The rings shall be designed so that they do not have to be removed during insulator replacement. However, provision is to be made for the removal of the rings if required for maintenance operations. In the case of aluminium grading rings, stainless steel bolts shall be used.

c) The rings shall be capable of sustaining a load of 2 kN (simulating a worker with tools standing on the ring) in the installed position.

d) Special attention is to be paid to the smooth finish not to enhance corona.

e) Grading rings should be as small as possible so that infringement of window clearances does not occur.

3.7 Yoke spreader assembly

If separate yokes are used to attach pairs of sub-conductors to each insulator string, a spreader assembly shall be provided to maintain proper insulator spacing. The spreader shall attach to the separate yokes and have sufficient flexibility to allow for unequal insulator lengths of ± 1 % of the insulator length and approximately 130 mm of movement when compressing an insulator string during maintenance.

3.8 Sag adjusters

When required by an enquiry document sag adjusters with specified adjustment shall be provided. The adjustment steps shall be dictated by the size and shape of the sag adjuster. Sag adjuster position on the strain assembly will depend on the conductor bundle arrangement and tower landing plate details. The design of the strain assembly will be checked for placement, size and number of sag adjusters required by Eskom. Turnbuckles shall not be used for the adjustment of sag.

3.9 Ball and socket hardware

a) Dimensions and tolerances of all ball and socket hardware shall be in accordance with SANS 60120. All dimensions shall be checked after galvanizing by the gauges specified in the above specification.

b) Stainless steel locking devices shall be used in all socket fittings. With the exception of the head of split pins, the dimensions and general requirements of SANS 60372-1 shall be met.

3.10 Bolts and nuts

a) Bolts and nuts shall be hexagon and, in general, meet the requirements of DIN EN ISO 898-1, except that shank and thread lengths may be non-standard. Alternatives to hexagonal fasteners including corona free nuts, must meet the mechanical and electrical requirements and allow for fastening and loosening with standard metric size hand tools.

b) No lock nuts shall be used. Split pins shall be provided to prevent the nut from working loose.

c) For shackle and clevis bolts, the bolt thread length and the position of the split pin, with the bolt head contacting the shackle or clevis side, shall be such that:

  1) The nut with washer shall not touch the side of the shackle, or clevis, when run to the end of the thread. Washer should be able to move freely at this position.

  2) Length of bolt shall be as short as possible, but still maintaining requirements set out in point a) above.

  3) The split pin can be freely installed.

d) Where connections on assemblies are subject to vibration and bolts can come loose, like jumper flags and deadends, these need to be supplied with suitable locking mechanisms like Belleville washers and or wedge type lock washers. Use of spring washers are not allowed. Supplier to prove suitability of any other type of locking mechanism before utilising the product.

3.11 Shackles and clevises

a) All shackles and clevises shall be supplied complete with all bolts, nuts, washers, split pins or other keeper pieces necessary.

b) For fittings with corona free nuts, the nut with split pin installed, shall not touch the side of the fitting with the bolt head bearing on the other side, nor shall there be more than a 5 mm space between the nut and the fitting side.

3.12 Split Pins

a) Hump back split pins shall not be used for Transmission lines and for Distribution lines utilising 120kN hardware. When assemblies for Distribution lines are being supplied, confirmation of split pin types and lengths must be received from the Distribution representatives, before production begins.

b) Split pins shall be made of stainless steel and conform to required specification.

3.13 Hardware strength classes

Each component of a suspension or strain assembly shall be of a strength class equal to the specified strength of the assembly. The supplier's choice of component shall, however, be subject to Eskom's approval.

The coupling ends of the components are to be designed using the following dimensions and guidelines given in table 2 below for insulators. These are to be used as guidelines only.

In general, the strength requirements for assemblies must be in accordance to Table 2 of section 4.2.2 of the SANS 10280-1:2017 edition 2.1.

This stipulates that the strain assemblies must be equal to the UTS of conductor bundle.

Suspension assemblies to be designed for the maximum load that result in the collapse of a superstructure.

Eskom would stipulate these requirements in conceptual hardware drawings. If not stipulated, the onus is on the manufacturer to request this.

Table 2: Strength class dimensions for hardware fittings

1	2	3	4	5	6	7	8
Strength Class	**120 kN**	**210 kN**	**300 kN**	**400 kN**	**530 kN**	**600 kN**	**900 kN**
SANS 60120 Designation Ball designation (IEC)	16	20	24	28	32	36	52
Socket designation (IEC)	16A	20	24	28	32	36	52
Bolt or Pin Diameter	16	22	24	28	32	36	52
Hole Diameter	17,5	24	26	30	34	37.5	53.5
Clevis Opening	18	20	26	26	26	38	52
Tongue Thickness	16	19	24	24	24	36	50

All dimensions given in the table above are in millimetres (mm).

Note: Where clevis-tongue couplings are specified, with exception for specific specified dimensions that deviate, they shall comply with the table of dimensions of clevis and tongue couplings for long rod insulators in SANS 60471.

3.14 Fabrication

a) Shearing and cutting of plates shall be neatly and accurately done. Mechanical guides shall be used when steel plates are flame cut. Cuts shall be clean and without ragged edges. Heat affected zones of flame cut plates shall be stress relieved. Flame cut edges shall be thoroughly ground in order to achieve the required thickness of zinc.

b) Holes in yokes or plate shall be drilled or sub-punched a minimum of 5 mm smaller than the diameter of the finished hole, and then drilled to size. This is not required in the case of hot- punched.

c) Holes in fittings shall be drilled to size, unless they are being hot-punched.

3.15 Welding

If welding is required, the manufacturer's procedure or welding standard shall be accepted by Eskom. Welding on individual components shall only be done after verification and acceptance by Eskom. Welding on hardware components shall not lessen the mechanical and material characteristics of the component. All activities associated with the welding process shall be completed prior to corrosion protection being implemented.

3.16 Corrosion Protection

a) All ferrous material except stainless steel shall be corrosion protected either by hot-dip galvanized in accordance with ISO 1461 or zinc thermal diffusion in accordance with SANS 53811. No material shall be coated until all shop operations have been completed. For Eskom purposes, all hardware supplied shall have a minimum local galvanising thickness of 85μm except threaded items and a zinc thermal diffusion thickness of not least than 70μm. The supplier shall inform Eskom in writing as to what their capabilities are if this specified thickness is not achievable.

b) All female threads in ferrous material shall be threaded after galvanizing, but shall be treated with an Eskom approved rust inhibitor. This practice is not required for zinc thermal diffusion.

3.17 Identification

Each component of hardware shall be marked for identification in accordance with SANS IEC 61284:1997-09 which includes the following:

Castings

a) identification of fittings -reference number specified minimum failure load

b) manufacturer's identification- company LOGO or name

c) date of manufacture (month and year)

d) cast code.

Forgings

a) identification of fittings -reference number specified minimum failure load

b) manufacturer's identification- company LOGO or name

c) date of manufacture (month and year)

d) cast code.

Links and plates

a) identification of fittings -reference number specified minimum failure load

b) manufacturer's identification- company LOGO or name

c) date of manufacture (month and year)

d) cast code.

Assemblies of fittings

a) identification of fittings -reference number specified minimum failure load

b) manufacturer's identification- company LOGO or name

c) date of manufacture (month and year)

d) cast code.

e) conductor diameter range or conductor code(s), as agreed between purchaser and supplier

f) bolt installation torque (unless breakaway torque bolts are used).

Conductor compression fittings

a) identification of fittings -reference number specified minimum failure load

b) manufacturer's identification- company LOGO or name

c) date of manufacture (month and year)

d) cast code.

e) conductor size or code name;

f) compression die sizes;

g) length to be compressed.

All identification marks shall be stamped, cast or forged in the metal in such a manner that all finished markings are permanent, distinct and legible.

3.18 Packing requirements

3.18.1 Packaging

a) All hardware less than one metre in length shall be supplied in wooden boxes or crates. No plastic sheets or plastic sacks are allowed.

b) Only identical assemblies or components shall be packed together.

c) Yokes and corona rings do not have to be boxed, but rather strapped and placed on wooden pallets.

3.18.2 Pallets

a) If it is intended to ship component boxes or components on pallets, the gross mass of the pallets shall not exceed 800 kg.

b) Pallets shall be suitable for handling by forklift trucks, capable of two-way entry and reversible.

3.18.3 Marking

All boxes and pallets shall be numbered consecutively from one upwards and marked generally in accordance with the following requirements:

1) Supplier's Name

2) Order Number

3) Gross Weight

4) Description of Material and Quantity

5) Project Name

6) Delivery Address

3.19 Quality Assurance requirements

Eskom's Quality Assurance Requirements are specified in QM58, or the latest Eskom specification.

The notification period shall make due allowance for inspection in their programmes. Eskom will not accept responsibility for late delivery or completion on the basis of inspection delays.

3.20 Approval of sub-contractors and suppliers

The tenderer shall give Eskom a full overview of all sub- contractors, local and outside of South Africa, names, addresses and what product/ component they are responsible for and which quality specifications have been applied. If at any stage the sub-contractor or supplier should change Eskom must be notified in writing.

4. Tests

4.1 Type test (Qualifying design test)

4.1.1 General

a) All tests must conform to SANS IEC61284: 1997

b) All tests shall be conducted by an Eskom accepted Laboratory. Main criteria is that the laboratory must have an ISO 9001 management system in place or a management system that conforms to ISO 9001.

c) Certain Key tests will be duplicated for verification purposes.

d) At tender stage, all tenderers shall supply tests, where applicable, to qualify their components of hardware as acceptable for Eskom's transmission and Distribution systems. This will be applicable for any individual items required by Eskom as well.

e) Each design type test, if successfully completed, shall be accepted by Eskom in writing. If a component fails a design test the component cannot be retested until Eskom has accepted the design modifications.

f) Each tenderer shall submit copies of each test certificate showing the results of the design tests.

g) During the contractual period, no design or manufacturing changes shall be made to the product without written approval of Eskom. Any modification or change shall be submitted to Eskom prior to its implementation and shall be approved in writing by Eskom.

h) Qualifying design tests are also referred to as Type Test.

i) Appendix A lists the required tests to be performed per product as per IEC 61284 and additional Eskom requirements.

j) Type test reports must contain test output limits and actual test outputs. This will verify immediately whether a component has passed that test or not.

4.1.2 Visual and dimensional tests

All items to be tested shall first be visually inspected by an Eskom representative to verify specification conformance regarding design, dimensions, fit and alignment.

All inspections and tests shall be controlled by means of the manufacturer’s product/ process quality plans.

Test reports/ certificates- Single copies of type test reports/ certificates and a sample routine test report shall be submitted to Eskom with the tender for approval. Two copies of the routine test reports accepted by Eskom’s representative shall be available with each shipment dispatched from the manufacturer’s works.

Inspection and witnessing of tests- Eskom reserves the right to appoint a representative to inspect the product prior to release for shipment, or at any stage of manufacture, and to be present at any tests. The manufacturer shall submit to Eskom, together with the tender documents, his quality plans, indicating all inspection hold points to which Eskom may add their witness, and hold points for inspection by Eskom or their appointed agents. The manufacturer shall make do allowance for these inspection points in his manufacturing programme and, to avoid delays, shall notify the date for inspection or witnessed tests at least 14 days in advance of the actual date.

Eskom will not accept responsibility for late delivery on the basis of inspection delays.

4.1.3 Material properties test

4.1.3.1 General

Test specimens taken from the final product and/or test bar, shall be subjected to the following tests in accordance with ASTM A370 or any international equivalent standard for mechanical testing of steel products and applicable documents:

a) Charpy V-notch impact energy test

b) Tensile test to determine:

   1) Ductility

   2) Percentage reduction in area

   3) Yield strength

   4) Ultimate tensile strength

   5) Flow Stress

c) A hardness test shall be conducted in accordance with ASTM E92 and applicable documents at the point of lowest cross-sections and at both extremities.

In the case where the final product is of such a size and geometry that test specimens cannot be machined, a suitable test bar needs to be supplied. For aluminium and cast iron products the test bar shall be prepared in accordance with BS EN 1559, BS EN 1676, BS EN 1706, BS EN 1559 and BS EN 1562 respectively. As an alternative a customised micro specimens can be machined in such a manner that reliable engineering test results will be obtained.

4.1.3.2 Acceptance criteria

a) The yield strength shall be in accordance with 3.2.2.

b) The flow stress shall be in accordance with 3.2.3.

c) The Charpy V-notch impact energy shall be in accordance with 3.2.4

d) The ductility shall be in accordance with 3.2.5

e) The percentage reduction in area and hardness shall be recorded.

f) The material properties of aluminium products shall be in accordance with BS EN 1559, BS EN 1676, BS EN 1706, BS EN 1559

4.1.3.3 Other examinations and tests to be performed

4.1.3.3.1 Metallographic examination

Hardware assembly components manufactured from heat treated materials or subject to heat treatment during fabrication shall be subjected to a metallographic examination across their longitudinal axis conforming to ASTM E384. This examination shall be required to determine that the heat treatment was carried out correctly and that the component microstructure is uniform throughout.

4.1.3.3.2 Microstructural examination

The specimen used for the microstructural examination shall also be subjected to a Vickers micro-hardness traverse test in accordance with ASTM E384. In components with sections greater than 10mm, 20 evenly spaced tests shall be carried out. In components with sections less than 10mm in their largest dimension, the tests shall be conducted at 0,5mm intervals. The results shall be recorded and compared with specified values.

4.1.3.3.3 Torque test

Suspension clamps requiring clamping bolts shall be installed over a rigid tube or rod equal in diameter to the smallest conductor for which the clamp is designed. All component parts shall withstand a torque of 200% of the installation torque without failure.

4.1.3.3.4 Slip Test

Suspension clamps shall be tested to Eskom’s approval to demonstrate that they can prevent the conductor slipping under a longitudinal conductor tension. This test shall be done in accordance with SANS IEC 61284 clause 11.4. Maximum allowable slip is 20%.(Eskom reserves the right to change the allowable slip.)

4.1.4 Strength and deformation tests

4.1.4.1 **General**

a) Each type of load bearing component of hardware ordered shall be subjected to the sequential loads specified herein, in a manner simulating service conditions. Each item shall be suitably gauge marked to indicate bending, buckling and elongation.

b) Test procedures involving yokes shall be subject to Eskom's acceptance

4.1.4.2 **Strength requirements**

The minimum failing load requirements for the load bearing components shall be as set out in an enquiry document.

4.1.4.3 **Mechanical damage and failure load test – AS per SANS IEC 61284**

The fitting shall be held in a tensile testing machine and the load shall be gradually increased until it reaches the specified minimum damage load **(67% of UTS).** This load shall be kept constant for 60 s. It shall then be removed and the measurement of the permanent deformation of the fitting carried out. Then the load shall be gradually increased until it reaches the specified minimum failure load at which it shall be kept constant for 60 s. Then the load shall be increased until the failure of the fitting occurs.

Note: For very high mechanical failure loads, when the safety of equipment and operators is at risk, the test may be stopped at 1,2 times the specified minimum failure load. In this case inspection by attributes shall be used.

Acceptance criteria

The damage load test is passed if no permanent deformation of the fitting greater than that agreed occurs at or below the specified minimum damage load.

Failure load the test is passed if failure of the fitting does not occur at a load less than or equal to the specified minimum failure load.

4.1.4.4 **Spreader assembly test**

The spreader assembly used in strain assemblies shall be loaded in a manner simulating service conditions and to Eskom's approval. A compressive load as indicated in Table 3, shall be applied for not less than one minute between sub-conductors (representing a faulty current load) without causing distortion.

Table 3: Spreader assembly test

TWIN CONDUCTORS 380 mm SPACING		
LOAD 20 kN	HORIZONTAL Between sub-conductors.	
QUAD CONDUCTORS 380 mm SPACING		
10 kN 12,5 kN	Horizontally between top and bottom pairs of sub-conductors. Diagonally between top and opposite bottom pairs of sub-conductors.	
LOAD 10 kN	REGULAR SQUARE 1) Horizontally between top and bottom pairs of sub-conductors. 2) Diagonally between top and opposite bottom pairs of sub-conductors.	DIAMOND SQUARE 1) Horizontally between the centre pair of sub-conductors 2) Vertically between the upper and lower sub-conductors 3) Diagonally between middle and an upper or lower sub-conductor.

SIX CONDUCTORS 320 mm SPACING		
LOAD 6,5 kN	REGULAR HEXAGON 1) Horizontally between top, centre and bottom pairs of sub-conductors. 2) Between top and centre sub-conductors and between centre and bottom sub-conductors on both sides of the assembly.	

4.1.5 Corona testing of hardware

4.1.5.1 **General**

a) Eskom requires all complete assemblies to be tested in accordance to SANS IEC 61284, point 14, CISPR 16-1 and CISPR 18-2.

b) Assemblies to resemble as close as possible what is to be used on site for projects. It is required that assemblies be tested with both composite and glass insulators as Eskom uses both types of insulation medium.

c) Facilities for testing should adhere to the requirements set out in the above mentioned specs and for confirmation; it is advised that Eskom be contacted (if possible), before hand to verify test setup and procedures.

d) The line hardware assemblies as contained in the line hardware specifications dictates the minimum distances between hardware corona rings to ensure that composite insulator suppliers can derive the maximum live end corona ring dimensions without causing clashing between the insulator and the hardware corona rings

The altitude above sea level where the power line will be operated must be taken into account when doing corona testing on representative suspension and strain assemblies. In order to avoid re-testing at various altitudes, it is recommended that a tower's hardware and corona rings be subjected to the most onerous conditions (maximum altitude and system voltage) and for the typical conductors the tower was designed for.

The relative air density where the line will operate once built, relative to the altitude where the testing will be done, must be taken into account using the relative air density at both altitudes. Two examples are given in Annex B.

The table below presents a sample of the most commonly found 765kV and 400kV suspension towers and associated strain tower series associated with them:

Tower type	**Conductor Bundles**	**Maximum Conductor Surface Electric Field Gradient (kV/cm)**	**Max Altitude (m)**	**Assembly**
529A 400kV	3 x Tern 450mm		1500m	I-String Suspension
529C 400kV	3xTern 450mm		1900m	I-String Suspension
520B 400kV (typically used with 518 series strain towers and 518H suspension)	4 Tern/4Zebra 450mm		1600m	V-Suspension Assembly
702B 765kV(typically used with 701 series strain towers)	6 Tern 320mm		1550m	V-Suspension Assembly
703B (typically used with 701 series strain towers)	6 Tern 320mm		1300m	V-Suspension Assembly
705C 765kV (typically used with 701 series strain towers)	6 Tern 320mm		1550m	I-String Suspension

If the maximum altitude where the specific hardware assembly can be used exceeds the altitude where the test facility is located, the test gradient must me adjusted upwards to the ration of the relative air density (RAD) differences as explained in Appendix B.

If the maximum altitude where the specific hardware assembly can be used is lower than the altitude where the test facility is located, the test gradient must me adjusted downwards to the ratio of the relative air density (RAD) differences as explained in Appendix B.

If and when Eskom adds new tower types, or when the supplier is not sure what the maximum design altitude is for a specific suspension tower and its associated strain towers are, the supplier is obliged to request these details prior to selecting the test parameters (altitude and maximum operating voltages).

The test voltage must represent the maximum system voltage, for example 800kV for the 765kV network, and 420kV for the 400kV networks, and 300kV for 275kV networks.

4.2 Material sample tests

4.2.1 General

a) Representative samples of all load bearing components of hardware shall be tested after the protective coating application. The suppliers shall submit copies of each test certificate showing the results of the sample tests.

b) Test certificates showing results of production sample tests shall be retained by the supplier for a minimum of five years for Eskom's inspection.

4.2.2 Sampling Procedure

a) Each component shall be sampled according to the batch size. A batch shall, within reason, consist of a single type, strength, and size of component, manufactured under essentially the same conditions, and in essentially the same time period.

b) The sample size from each batch, for each test, shall be 0,5% of the batch size for suspension assembly components and 2,0% of the batch size for strain assembly components. A minimum of five samples per batch is required.

c) Samples shall be selected at random, without regard to their quality and be representative of the entire batch.

d) Test specimens taken from the final product and/or test bar, shall be subjected to the following tests in accordance with ASTM A370 and applicable documents:

e) Charpy V-notch impact energy test

f) Tensile test to determine:

  1) Ductility

  2) ii) Percentage reduction in area

  3) iii) Yield strength

  4) iv) Ultimate tensile strength

  5) v) Flow Stress

g) A hardness test shall be conducted in accordance with ASTM E92 and applicable documents at the point of lowest cross-sections and at both extremities.

In the case where the final product is of such a size and geometry that test specimens cannot be machined, a suitable test bar needs to be supplied. For aluminium and cast iron products the test bar shall be prepared in accordance with BS EN 1559, BS EN 1676, BS EN 1706, BS EN 1559 and BS EN 1562 respectively. As an alternative customised micro specimens need to be machined in such a manner that reliable engineering test results will be obtained.

4.2.3 Acceptance criteria

a) The yield strength shall be in accordance with 3.2.2.

b) The flow stress shall be in accordance with 3.2.3.

c) The Charpy V-notch impact energy shall be in accordance with 3.2.4

d) The ductility shall be in accordance with 3.2.5

e) The percentage reduction in area and hardness shall be recorded.

f) The material properties of aluminium products shall be in accordance with BS EN 1559, BS EN 1676, BS EN 1706, BS EN 1559.

4.2.4 Plate

All plate used in the fabrication of yokes shall be ultrasonic inspected in accordance with BS EN 10160 or Eskom accepted equal. Certification reports shall be available for Eskom's approval.

4.2.5 Strength and deformation tests

4.2.5.1 General

Samples of each component shall be subjected to the following tests. Loads shall be applied in a manner simulating service conditions.

4.2.5.2 Mechanical damage test

The fitting shall be held in a tensile testing machine and the load shall be gradually increased until it reaches the specified minimum damage load (67% of UTS). This load shall be kept constant for 60 s. It shall then be removed and the measurement of the permanent deformation of the fitting carried out. In addition the component shall show no visual evidence of cracks and it shall be possible to disassemble items by hand, except for split pins and nuts. If it is visually obvious that components can be disassembled by hand, disassembly need not be performed.

a) After completion of the above test, the applied load shall be gradually increased until it reaches the specified minimum failure load at which it shall be kept constant for 60 s. Then the load shall be increased until the failure of the fitting occurs. From the values n (number of items tested) and y (load at failure), the mean $(\sum y)/n$ and the standard deviation,

$$s = \sqrt{\frac{\sum (y - (\sum y)/n)^2}{n-1}}$$

shall be computed.

b) If the first test sample from a batch withstands a load exceeding its minimum failing load by 20 % (120%) without failure, the test may be stopped at that load. However, all subsequent samples from the same batch shall also not fail at 120 % of the minimum failing load. If any sample fails at a load less than 120 % of the minimum failing load, the samples shall be retested to failure and the standard deviation calculated.

c) Rejection criteria

d) The entire batch represented by the samples tested shall be rejected if:

   1) Any sample fails to meet the disassembly requirements or shows visual defects after application of 67 % of the minimum failing load.

   2) Any sample fails at a value less than the minimum failing load specified.

   3) The mean of the samples tested is less than the minimum failing load specified plus three standard deviations unless all samples exceed 120 % of the minimum failing load.

4.2.5.3 **Porosity Test**

Aluminium and cast iron products (castings) shall be selected at random, by means of the sample procedure as explained in point 4.2.2 for testing. These samples shall be longitudinally cut followed by visual inspection of the sections. Findings shall be recorded.

4.2.5.4 **Corrosion protection coating test**

The suppliers shall submit test certificates showing the results of tests and inspections. For hardware manufactured in South Africa, tests shall be performed to the satisfaction of the South African Bureau of Standards.

4.2.5.5 **Socket split pin or W-clip test**

Split pins or W-clips used in socket fittings shall meet the requirements of SANS 60372.

4.3 Production routine tests

4.3.1 General

a) All items of hardware produced shall be visually inspected in accordance with an Eskom accepted technique sheet for defects by the supplier, before any tests are carried out and packaging occurs. A fully assembled assembly of each type shall be available for inspection before any items are released for testing. This will be done to verify fitment and adaptability of each component.

b) Defective components shall be permanently marked and discarded.

c) Test certificates showing results of production routine tests, shall be retained by the supplier for a minimum of five years, for Eskom's inspection.

d) At its discretion, Eskom reserves the right to submit randomly selected items of hardware delivered to site to qualifying design tests. The cost of testing shall be to Eskom's account for items that pass the tests and to the supplier's account for items that fail. Failure to pass qualifying design tests will result in rejection of all items until the problem is satisfactorily resolved.

4.3.2 Non-destructive testing

Ferrous components shall be tested before galvanizing by one of the following methods. All certificates must be produced after the tests have been conducted to verify that there are no hidden defects within the developed item.

1) magnetic test

2) eddy current test

3) radiograph test

4) ultrasonic test

5) dye penetrant test

4.3.3 Crack detection tests

All aluminium load bearing components and welds shall be tested by a process accepted by Eskom.

4.3.4 Tensile proof test

All load bearing components, except suspension and strain yokes, shall be loaded to 40 % of the minimum failing load specified in section 4.1.4.2. The load shall be held for at least 10 seconds. Any item showing visible evidence of permanent deformation, cracks or incipient failure shall be rejected.

5. Authorization

This document has been seen and accepted by:

Name and surname	**Designation**
Faith Mokhonoana	Senior Manager- Lines Engineering Services
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6. Revisions

Date	Rev.	Compiler	Remarks
Aug 2023	1	B. Haridass	Changes to requirements and addition of new requirements like special bolts and nuts for jumper flags and deadends, plus addition of new Corona testing requirements.

7. Development team

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

- Dr Bertie Jacobs
- Ockert Fourie
- Dr Jacques Calitz

8. Acknowledgements

Not applicable.

Annex A –

Test Matrix for hardware, spacers and spacer dampers, plus vibration dampers.

Remark	Test	Insulator set fittings and			Suspension Clamps			Tension Joints and Tension		
		Type Tests	Sample Tests	Routine Tests	Type Tests	Sample Tests	Routine Tests	Type Tests	Sample Tests	Routine Tests
Clause 7,8 IEC 61284	Visual and Dimensional Examination, material and mass	x	x	x	x	x	x	x	x	x
Clause 11 IEC 61284	Failure Load Test on Component	x	x		x	x		x	x	
Clause 11 IEC 61284	Torque Test as per IEC 61284				x	x		x	x	
Clause 11 IEC 61284	Slip Test (Clamp Slip Test)				x	x		x	x	
Clause 10 IEC 61284	Hardness Test	x	x		x	x		x	x	
Clause 9 IEC 61284	Galvanizing Test (Corrosion Protection)	x	x		x	x		x	x	
Clause 12 IEC 61284	Magnetic Losses Test				x			x		
Clause 13 IEC 61284	Heat Cycle Test				x			x		
Clause 14 IEC 61284	Corona and RIV Test	x			x			x		
Clause 5.2.5.4 of spec 240-60777474.	Porosity Test	x	x		x	x				
Clause 5.3.2 of spec 240-60777474.	Magnetic Particle Test	x	x	x	x	x	x			
Clause 5.1.4 of spec 240-60777474.	Deformation Test / Tensile Test	x	x		x	x	x			
These test are done normally on a sample specimen cut and machined from the fitting as per Clause 5.1.3 of spec 240-60777474.	Metallographic Examination	x			x			x		
	Microstructural Examination	x			x			x		
	Charpy V-Notch Impact	x	x		x	x		x	x	
	Ductility	x	x		x	x		x	x	
	% Reduction Area	x	x		x	x		x	x	
	Ultimat Tensile Strength	x	x		x	x		x	x	
	Flow Stress	x	x		x	x		x	x	
	Yield Strength Test	x	x		x	x		x	x	

x - Tests which shall be performed

x' - If Applicable

		Partial Tension Fittings			Repair Sleeve			Insulator Protective Fittings		
Remark	Test	Type Tests	Sample Tests	Routine Tests	Type Tests	Sample Tests	Routine Tests	Type Tests	Sample Tests	Routine Tests
Clause 7,8 IEC 61284	Visual and Dimensional Examination, material and mass	x	x	x	x	x	x	x	x	x
Clause 11 IEC 61284	Failure Load Test on Component	x						x		
Clause 11 IEC 61284	Torque Test as per IEC 61284	x	x							
Clause 11 IEC 61284	Slip Test (Clamp Slip Test)	x								
Clause 10 IEC 61284	Hardness Test									
Clause 9 IEC 61284	Galvanizing Test (Corrosion Protection)							x	x	
Clause 12 IEC 61284	Magnetic Losses Test									
Clause 13 IEC 61284	Heat Cycle Test	x			x					
Clause 14 IEC 61284	Corona and RIV Test	x			x			x		
Clause 5.2.5.4 of spec 240-60777474.	Porosity Test	x								
Clause 5.3.2 of spec 240-60777474.	Magnetic Particle Test							x	x	
Clause 5.1.4 of spec 240-60777474.	Deformation Test / Tensile Test									
These test are done normally on a sample specimen cut and machined from the fitting as per Clause 5.1.3 of spec 240-60777474.	Metallographic Examination	x								
	Microstructural Examination	x								
	Charpy V-Notch Impact									
	Ductility									
	% Reduction Area									
	Ultimat Tensile Strength									
	Flow Stress									
	Yield Strength Test									

x - Tests which shall be performed

x' - If Applicable

		Spacer Damper			Flexible Spacer			Rigid Spacer		
Remark	Test	Type Tests	Sample Tests	Routine Tests	Type Tests	Sample Tests	Routine Tests	Type Tests	Sample Tests	Routine Tests
Clause 7,8 IEC 61284	Visual and Dimensional Examination, material and mass	x	x	x	x	x	x	x	x	x
Clause 11 IEC 61284	Failure Load Test on Component									
Clause 11 IEC 61284	Torque Test as per IEC 61284	x	x		x	x		x	x	
Clause 11 IEC 61284	Slip Test (Clamp Slip Test)	x			x			x		
Clause 10 IEC 61284	Hardness Test									
Clause 9 IEC 61284	Galvanizing Test (Corrosion Protection)	x'	x'		x'	x'		x'	x'	
Clause 12 IEC 61284	Magnetic Losses Test									
Clause 13 IEC 61284	Heat Cycle Test									
Clause 14 IEC 61284	Corona and RIV Test	x			x			x		
Clause 5.2.5.4 of spec 240-60777474.	Porosity Test	x	x		x	x		x	x	
Clause 5.3.2 of spec 240-60777474.	Magnetic Particle Test									
Clause 5.1.4 of spec 240-60777474.	Deformation Test / Tensile Test									
Clause 7.7.2 IEC 61854	Electrical Resistance Test	x			x'			x		
Clause 7.6 IEC 61854	Tests to Characterise Elastomers	x			x'					
Clause 7.8, D2 IEC 61854	Vibration behaviour verification bundle/spacer system **Aeolian Vibration**	x			x					
Clause 7.8, D3 IEC 61854	Vibration behaviour verification bundle/spacer system **Subspan Oscillation**	x			x					
Clause 7.5.2 IEC 61854	Breakaway Bolt Test	x	x		x	x		x	x	
Clause 7.5.4 IEC 61854	Simulated short-circuit current test and compression and tension test	x			x			x		
Clause 7.5.5 IEC 61854	Characterisation of the elastic and damping properties	x			x					
Clause 7.5.6 IEC 61854	Flexibility Tests	x			x					
Clause 7.5.7 IEC 61854	Fatigue Tests	x			x					
IEC 61854	Damper Performance Test									

x - Tests which shall be performed

x' - If Applicable

Tests on dampers

Remark	Test	Stockbridge damper		
		Type Tests	Sample Tests	Routine Tests
IEC 61897: 1998-clause 7.1	Visual examination	x	x	o
IEC 61897: 1998-clause 7.2	Verification of dimensions, materials and mass	x	x	
IEC 61897: 1998-clause 7.3	Corrosion protection tests	x	x	
IEC 61897: 1998-clause 7.4	Non-destructive tests	o	o	o
IEC 61897: 1998-clause 7.5	Clamp slip test	x	o	
IEC 61897: 1998-clause 7.6	Breakaway bolt test (1)	x	x	
IEC 61897: 1998-clause 7.7	Clamp bolt tighteneing test	x	x	
IEC 61897: 1998-clause 7.8	Attachment of weights to messenger cable	x	x	
IEC 61897: 1998-clause 7.9	Attachment of clamp to messenger cable test	x	x	
IEC 61897: 1998-clause 7.10	Corona and radio interference voltage (RIV) tests	x (1)		
IEC 61897: 1998-clause 7.11	**Damper performance test**			
IEC 61897: 1998-clause 7.11.2	Damper characteristic test	x	o	
IEC 61897: 1998-clause 7.11.3	Damper effectiveness evaluation	x		
IEC 61897: 1998-clause 7.12	Damper fatigue test	x		
		x	x	

Annex B –

Test Matrix for hardware, spacers and spacer dampers, plus vibration dampers.

Example 1 – Test facility at an altitude of 1500m, and the line to be built at 2200m (the maximum for a specific conductor bundle and tower combination)

Conductor bundle	Suspension Tower	Max Surface Gradient (kV/cm)	Type of assembly	Altitude(m)
4 x Zebra 450mm	528A	14.85	Suspension	1700

Test Facility:

CSIR Netfa

Altitude = 1500m

Relative air density (RAD) at the test facility will be higher than where the line can be built using the 528A suspension assembly.

The generalized definition of relative air density as a function of altitude can be used:

$$RAD = e^{-0.000116 \times Altitude}$$

RAD at Netfa Test Facility	0.840297
RAD at the maximum altitude where a line can be built using the 528A with 4 Zebra conductor bundle	0.821026

The air density will be lower at 1700m than for the Netfa Test altitude, hence the ratio of the RAD values can be used to scale up the test gradient to compensate for the difference.

Hence the test gradient is modified as follows : (where test altitude is lower than where the line will operate)

$$Test\ Gradient = Max\ Surface\ Graddient\ x\ \frac{RAD\ (Test\ facility\ altitude)}{RAD\ (Line\ maximum\ altitude)}$$

Therefore, the Test gradient is as follows:

$$Test\ Gradient = 14.85\ x\ \frac{0.840297}{0.821026} = 14.85x1.023471 = 15.2\ kV/c$$