REVISION CONTROL

Revision No.	Notes	Date
01	Minor corrections; Updated insulator specification.	15 July 2015
02	Minor corrections. Updated spacer specification. Added marker sphere specification. Updated standard references. Add step bolt with eye specification.	18 February 2020
03	Updated the geotechnical design parameters, foundation systems, requirements for soft and hard rock foundations, conductor spacings, shielding angle, earth bonding points, descriptions for tower types and tower capacity.	06 April 2021
04	Minor corrections, updates and additions in various parts of the document, such as: 1.9 Testing 1.10 Packing 1.13 Measurement for Payment 1.14 Reimbursement for Variations 2.3 Route survey 3 Foundations- related to pricing format and reimbursement; concrete cover over steel 3.6.6 Concrete foundations 4.12.2 Step bolts 4.13.1.4 ACD 4.13.2 Tower Labels 5.8 Drums 5.9 Tests 6.17 Packing 7.19.6 Tension clamp for OPGW 8.2 Environmental management 8.4 Bush clearing and relocation of services 8.5 Foundations 8.7.3 Crossings, notices and permits	30 August 2022

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1.0 General

1.1 Scope

1.1.1 The specification covers the technical requirements for the design, manufacture, testing, packing, packaging, transport, storage and installation of materials that make up 132 kV and 275 kV steel lattice overhead power lines in eThekwini Electricity.

1.2 Service conditions

1.2.1 The equipment shall be suitable for operation at sea level in an area categorized as a tropical climate zone. The incidence of lightning in this area is high. The pollution category is a combination of medium to high marine and high industrial, categories C4-high/ C5-low. Climatological data is given in the **Technical (Returnable) Schedules**.

1.2.2 All surfaces subject to corrosion shall have a finish to withstand the action of a humid salt laden atmosphere. Hence all equipment must be designed for operations in the severe tropic climate conditions and fully comply with climatic aging tests as per IEC 60932-Class 2.

1.2.3 When choosing materials and finishes, the Contractor shall give due regard to this operating environment.

1.2.4 All materials shall be rodent and vermin proof. Packaging materials which may be used for storage of the materials for extended periods of time shall also be rodent and vermin proof and be treated against fungus attack.

1.3 Standards

1.3.1 The design, manufacture and testing of the equipment provided shall be strictly in accordance with this Specification and standards specified in this Specification. The latest revision or edition in effect at the time of issuing of this Specification for bidding purposes shall apply. The Bid documents do not contain a full list of standards to be used; specific ones are referred to for clarification of particular requirements.

1.3.2 Ratings, characteristics, tests and test procedures for the materials/ equipment covered by this Specification shall comply with the provisions and requirements of the standards of the International Electrotechnical Commission (IEC), South Africa Bureau of Standards (SABS) and eThekwini Electricity's operational and specific requirements. Where these standards are non-existent for a particular item or issue, other standards, such as British Standards, shall be complied with, as may be expressly stated. Furthermore, where these standards do not fully cover all provisions and requirements for design, construction, testing, etc., recognized National Standards or Best Practices shall be applied.

1.3.3 The Bidder shall specifically state the precise standard, complete with identification number, to which various materials and equipment are manufactured.

1.4 Associated specifications

1.4.1 Associated Specifications from the Employer which form part of the Bid document are listed in the **Scope of Work, Technical (Returnable) Schedules, Other Specifications and Drawings.**

1.5 Statutory requirements

1.5.1 All apparatus and materials supplied and all work carried out shall comply in all respects with the regulations and provisions of the Occupational Health and Safety Act, 85 of 1993, as amended, SANS 10280-1, the Mines and Works Act No. 27 of 1956, as amended, the Explosives Act no 26 of 1956, as amended, and with any other applicable regulations and legislations to which the Employer and Contractor may be subject.

1.5.2 Power line crossings of roads, railways, communications lines and other power lines shall comply with the requirements and regulations, statutory or otherwise, of the responsible authority.

1.5.3 Where the Contractor is required to work on plant that is in use for the Employer's service or under test, the Contractor or his Representative shall comply fully with the Employer's Safety Rules regarding electrical apparatus and the safety of the personnel working thereon. No testing or other work on parts which are liable to be electrically charged from any source shall be permitted except under "Permit to Work" which will be issued for the purpose by the Employer's authorized personnel.

1.5.4 Notices which are compulsory as per legislation or statutory requirements shall be installed to ensure compliance. Other notices, when called for in Scope of Work, shall be installed upon approval by the Employer's Engineer. All notices and the details on these shall be of suitable sizes and quality, and to the approval of the Employer's Engineer.

1.5.5 Tower and circuit identification shall be via labels showing route designation, tower number, circuit number and phase configurations.

1.6 Unit of measurement and language

1.6.1 The metric units of measurement shall be used in all documents. In existing documents or documents supplied by others where other units have been used, the equivalent metric unit shall be added by the Bidder/ Contractor.

1.6.2 All documents, correspondence, drawings, reports, schedules, instructions, and nameplate readings of the equipment shall be in English.

1.7 Working stress and plant and equipment design

1.7.1 The design, dimensions and materials of all parts shall be such that they will not suffer damage under the most adverse conditions nor result in deflections and/or vibrations, which might adversely affect the operation of the plant and equipment. Mechanisms shall be constructed to avoid sticking due to rust or corrosion.

1.7.2 The components, parts and/or equipment shall be designed and manufactured in the best and most substantial and workman-like manner with materials best suited to their respective purpose and generally in accordance with up-to-date recognized standards of good practice. The manufacturing plant and equipment shall be adequately maintained, serviced, re-tooled, calibrated, tested, etc., to ensure high quality and production to design specifications.

1.7.3 All parts/ components/ equipment shall be designed to minimize the risk of fire and consequential damage, to prevent ingress of vermin, dust and dirt, and accidental contact with electrically energized or moving parts. The plant and equipment shall be capable of continuous operation with minimum attention and maintenance in the severe conditions likely to be obtained in the tropical climate.

1.7.4 Upon request by the Employer Engineer or authorised Representative, complete information regarding the design assumptions, loading and operating conditions, deflections and unit stresses used in the design shall be provided by the Contractor.

1.7.5 Short-circuit ratings required are given in the **Technical (Returnable) Schedules**. For all current carrying parts the permissible short circuit duration shall be at least 1 second, unless stated otherwise.

1.8 Materials and workmanship

1.8.1 All materials supplied shall be new and of the best quality and of the class most suitable for the working conditions specified. The items shall be robust enough to withstand the variations in temperature and atmospheric conditions arising under working conditions without distortion, deterioration or undue stress in any parts and also without affecting the performance of the various parts of the Plant and/or Equipment for which it has been designed.

1.8.2 The parts, components, equipment, plant shall be designed and constructed for a useful life of 40 years. Any item, component or equipment with a shorter life cycle shall be identified and so arranged that they can be easily removed and replaced.

1.8.3 All materials shall comply with the latest issues of the approved and formally released specified standards unless otherwise specified or permitted by the Employer. Where standards provide options, and the applicable options have not been explicitly stated in these specifications and the Employer's **Scope of Work, Technical (Returnable) Schedules, Other Specifications and Drawings**, the Contractor shall not automatically offer materials with the minimum requirements; the Contractor is required to consult with the Employer's Engineer on specific requirements.

1.8.4 Workmanship shall be of the highest class throughout to ensure that the final product meets the design and guaranteed specifications.

1.8.5 All parts shall conform to the dimensions shown in the product documents, data sheets and approved specifications. All joints, datum surfaces and meeting components shall be machined. All machined surfaces shall be shown on the drawings. All fastener components shall conform to the metric standards, unless otherwise required for replacement of non-metric parts on a like-for-like basis. The Contractor/ Supplier /Manufacturer shall never incorporate any standards or size system by his own account, regardless of that accepted and incorporated in this Specification and/or associated **Schedules**.

1.8.6 Upon request by the Employer Engineer or authorised Representative, complete information regarding the Quality Management and Control Processes shall be provided by the Contractor (or the Supplier /Manufacturer via the Contractor).

1.9 Testing

1.9.1 Manufacturers shall be responsible for performing or for having performed all tests on materials, components and equipment, and these shall have successfully passed, in accordance with the relevant normative (international and national) references and standards and those stated in the Employer's scope of work and specifications. Bidders shall confirm the Manufacturer's capabilities in this regard when submitting bids. Any limitations shall be clearly specified.

1.9.2 Type test reports and certificates shall be certified by the national standards and testing authority of the country of origin. Where a body other than a national standards and testing authority is used to certify the type test reports, a copy of the certificate of accreditation shall be attached. The current contact details of the testing and certification authority shall be provided at the time of bidding.

1.9.3 Upon completion of the manufacturing process, routine tests shall be carried out as per the respective standards for each equipment and the results endorsed by the national standards and testing authority of the country of manufacture or the accredited body.

1.9.4 All materials shall comply with the test criteria stipulated in the relevant standards, and the Employer's acceptance of the conductors and accessories shall not relieve the Contractor of his responsibility for meeting all the requirements of this specification.

1.9.5 The Contractor shall carry out at his own expense all tests necessary to ensure the satisfactory design and manufacture of components in accordance with the relevant standards.

1.9.6 Test reports shall be made available to the Employer. The Contractor shall bear the cost of the tests and for furnishing the records and reports.

1.9.7 The costs of all tests, specified or recommended by the relevant national and international standards, relevant national statutory legislation, and/or this specification and the Scope of Work for the project, shall be included in the costs of the materials, components, equipment, plant. If any specific test is required, over and above any test that should be done by the Manufacturer, payment shall be made using the unit rates quoted in the **Price Schedules (Bill of Quantities)**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

1.10 Packing

1.10.1 Each item shall be packed properly and be protected for transportation from the place of manufacture to site (i.e. at the point of use).

1.10.2 Each crate of package shall contain a packing list in a waterproof envelope and a copy in triplicate shall be forwarded to the Employer prior to dispatch. All packaged items shall be clearly marked for easy identification against the packing list.

1.10.3 Long pieces of steel angles shall be packed in bundles and properly tied together in an approved manner (not to damage the galvanizing) and care shall be taken to ensure that they are robust and not of excessive length and weight for handling in transit. Damaged steel angles and/or galvanizing shall result in rejection of the steel angles.

1.10.4 Short pieces of steel angles and steel plates shall be bolted or wired together through holes and packed in stout timber cases.

1.10.5 Bolts, nuts, washers and fillers shall be bagged in sealed vinyl and packed in steel cans. The cans shall be crated together.

1.10.6 Packing together of components of dissimilar metals shall not be acceptable.

1.10.7 Phase conductors and earth wires shall be packed on drums- further requirements are detailed in the section dealing with the conductor specification.

1.10.8 The Employer shall reserve the right to inspect (or request for the necessary information) and approve the packaging before the items are dispatched. The Contractor (in conjunction with its Supplier) shall be entirely responsible for ensuring that the packing is suitable for transit and such inspection and approval will not relieve the Contractor from responsibility for any loss or damage due to faulty/ incorrect packaging.

1.11 Delivery

1.11.1 The Contractor (in conjunction with its Supplier) shall ensure delivery of all materials to site in adequate time for construction according to the **Delivery Schedule**.

1.11.2 Each delivery notification shall include a complete shipping list of the contents of each package to be delivered and shall indicate the anticipated date of delivery, serial number of each component where applicable, and evidence of the insurance cost arranged for it.

1.12 Programme and progress

1.12.1 Within 21 days after date of contract award, the Contractor shall prepare and submit a detailed program covering the entire scope of works, in sufficient detail to define the various sections of work. If the software used is one for which a licence is required, then the Contractor shall also provide the programme in Excel and pdf. A digital (electronic) copy shall be signed and dated and then submitted to the Employer's Engineer for approval.

1.12.2 Regular monthly progress reports shall be provided by the Contractor, indicating:

(1) The actual state of the progress of all items during the course of inspections, manufacture and/or construction.

(2) Resources (human and machines) used for the applicable period.

(3) Work days- target and actual.

(4) Risks (technical, delivery, resources, time, site related, etc.) and mitigation measures.

1.12.3 The Contractor shall keep detailed and accurate records of all schedules, including modifications.

1.12.4 The Contractor shall keep photographic records of the progress of each stage of the work, and submit these electronically and in high resolution to the Employer's Engineer during each stage. The determination of each particular stage shall be agreed upon between the Contractor and the Employer's Engineer/ Agent after contract award and as work progresses. Additionally, upon completion of the work, the Contractor shall submit a set of digital colour photographs on a portable USB memory device with explanatory description adequately edited in book form to the Employer's satisfaction.

1.13 Measurements for payment

1.13.1 Line length shall be measured along the centre line of the power line without allowance for sag and differential elevation effects for phase conductors and standard earth wires. Conductor allowance for sag and differential elevation effects, downleads, clamping and stringing off-cuts shall be included for payment if this is specified as allowed in the Scope of Work.

1.13.2 Weight shall be measured to the nearest kilograms, with the steel density as detailed in the tower specification section of this Specification.

1.13.3 Excavations, where it is necessary to measure, such as for payment purposes, shall be measured to the nearest 100 mm.

1.13.4 Ground will be deemed to be normal, regardless of the nature of the ground, the presence of water, the slope or irregularity of the ground surface and other local conditions, unless the Contractor's Engineers certify that the conditions are abnormal and this is accepted by the Employer's Engineer or Authorised Representative. No extra payment shall be made for additional encasing concrete required owing to the slope of the ground.

1.13.5 Where the Contractor deems ground conditions to be abnormal, these shall be substantiated by a full report compiled by a Professional Geologist or Professional Engineer, and confirmed together with changes to the soil nomination and foundation designs by the Contractor's Geotechnical and Structural Engineers involved in the soil investigation and foundation designs. Where allowance is made in the Price Schedules (Bill of Quantities) for separate payment to the Contractor for soil investigations and foundation designs, then the Contractor shall be reimbursed for the report, subject to approval by the Employer's Engineer. Full details shall be provided to the Employer's Engineer who will make the final decision regarding whether additional payment for such conditions shall be payable. Where the Contractor's Engineer has certified that the ground conditions are abnormal and this is accepted by the Employer's Engineer, additional ground work required will be paid for using

unit rates quoted in the **Price Schedules (Bill of Quantities)**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

1.13.6 Payment for modifications to parts of standard towers or addition of parts shall be by agreement between the Contractor and Employer's Engineer. The Contractor shall be reimbursed using unit rates quoted in the **Price Schedules**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

1.14 Reimbursement for Variations

1.14.1 Variations are any change to the works, such as variation of form, quality or quantity of the works, or any part thereof that may be necessary, or for any reason appropriate for the completion of the works.

1.14.2 Any work that is to be executed for which there are quoted unit rates in the **Price Schedules (Bill of Quantities)** and the quantities are re-measurable shall not be deemed to be a Variation.

1.14.3 The value of the variations shall be calculated by the Employer's Engineer, or jointly by the Employer's Engineer and the Contractor, and be subject to approval by the Employer's Engineer prior to work commencement.

1.14.4 The Contractor shall be compensated for the expense incurred, i.e. the reimbursable expense.

1.14.5 Pricing for the variation shall be done using one or more of the following:

(1) Where the work is of a similar character and to be carried out under similar conditions to work priced in the **Price Schedules**, it shall be valued at such rates and/or prices contained therein as may be applicable.

(2) Daywork rates.

(3) Quotations from Subcontractors. This will be at cost plus mark-up as may be allowed in the contract.

1.14.6 Proper records and evidence of work activity shall be kept and schedules, (such as timesheets, vehicle usage, material lists, tools and equipment utilisation, specialist service details, etc), shall be compiled and submitted to the Employer's Authorised Representative for review and thereafter to the Employer's Engineer for approval, prior to submitting claims for reimbursement.

1.14.7 The Employer's Engineer/ Agent reserves right to reject the whole variation claim or part thereof where such is not properly substantiated and/or where the claim is not proportionate to the output.

1.15 As-builts

1.15.1 The Contractor shall provide as-built profiles/ templates and documentation for the completed work, in a format approved by the Employer's Engineer.

1.15.2 All documentation shall be in hardcopy and digital (electronic) copy. The electronic copy shall be in editable and non-editable format, to allow for updates during operations, maintenance and future modifications.

1.15.3 The as-builts shall comprise the following, and any other documentation that may form part of the close-out:

(1) Scope of Work as executed.

(2) Tower schedules, with tower coordinates.

(3) Line design package, with the PLS-CADD files.

(4) Soil investigation report and results.

(5) Foundations drawings, and detailed technical data on materials used, including details of the concrete and load bearing ratings.

(6) Tower datasheets and drawings (outline and detail per section) and test reports. This shall include adequate dimensional detail, weight per steel item and fasteners for subsequent repairs and maintenance.

(7) Components drawings from the Manufacturers which shall include product codes, material details and dimensions. Any item that defers from the Specifications shall be changed before submission, to reflect the as-supplied and as-built state.

(8) Hardware assembly drawings, including insulators. The drawing shall not be generic, but represent the components as close as to the as-builts.

(9) Profile drawings, showing, amongst other things, strip plan, tower types, tower positions, and clearances between conductors and ground and/or obstructions at 75 °C, (or other templating temperature used in the design as may be specified by the Employer's Engineer).

(10) Sag and tension tables- Initial Conditions, Creep Conditions, and Actual as-built Values.

(11) A list of all components including the Manufacturer's and local Supplier's contact details for operation and maintenance purposes.

(12) Any other documentation compiled for the purpose of executing the work in compliance with the Employer's Specifications and Statutory requirements. This shall include the Health and Safety file.

2.0 Route survey and spotting

2.1 General

2.1.1 The transmission line route will be located within servitudes or wayleaves, being on strips of land whose boundaries will be indicated by the Employer.

2.1.2 All design documentation shall be provided by the Contractor, unless otherwise stated in the **Scope of Work**, in hard copy and digital (electronic) format. All setting out documentation shall be provided by the Contractor in hard copy and digital (electronic) format. The paper hardcopies shall be to the sizes determined by the Employer's Engineer. The digital files shall be in the same format as the application used, and in a portable format for use by personnel who don't have the application software, such as Excel and pdf.

2.2 Information provided by Employer

2.2.1 The Employer will provide the following upon contract award:

(1) Line route plans.

(2) Servitudes and/or wayleaves details.

(3) Route survey and ground profiles, if stated in **Scope of Work**.

(4) Positions of towers, particularly angle and terminal towers, which were determined during wayleave negotiations.

(5) Details of any areas with specific constraints in positioning intermediate towers.

(6) Any specific setting out details required.

2.2.2 Route plans and ground profiles issued by the Employer may show proposed tower positions, however these are not final and are merely used for quantity estimation, feasibility and servitude negotiation. These do not absolve the Contractor from performing a complete design, unless otherwise specified in the **Scope of Work**.

2.3 Route survey

2.3.1 The Employer shall provide the detailed survey of the route survey to the Contractor for line design purposes if the design is to be done by the Contractor. Alternatively, the Contractor shall undertake the route survey if specified in the **Scope of Work**, or if requested by the Employer's Engineer. All survey work (ground based or aerial based) shall be carried out by competent and registered Surveyors who are familiar with the requirements and working conditions. The Contractor shall be reimbursed as per unit rates quoted in the **Price Schedules (Bill of Quantities)**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

2.3.2 Where the Employer provides the survey and ground profile information, the Contractor shall note that these may have been obtained several months prior to contract award. Hence the Contractor is required to verify that the survey information is still accurate by means of a route inspection. If further survey data is required to correct inaccuracies due to subsequent developments, this shall be carried out by the Contractor unless stated otherwise in the **Scope of Work**. Payment shall be as per unit rates quoted in the **Price Schedules**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

2.4 Tower spotting

2.4.1 The Contractor shall utilize the latest version of PLS-CADD software developed by Power Line Systems to determine the optimum location and height of towers in accordance with the specified design parameters.

2.4.2 The results of the spotting shall be shown on profile sheets, illustrating conductor clearance to ground, which are to be supplied in hard copy and digital format.

2.4.3 The Contractor shall conduct a Line Walk-down to confirm the suitability of the tower positions as per the tower spotting, and perform the necessary changes to suit the ground conditions or other specified requirements. The Employer's Engineer may, within reason, request for changes to the tower positions.

2.4.4 In addition to the profile sheets, the following reports shall also be supplied by the Contractor in digital (electronic/ softcopy) format: staking table, wind and weight span reports, stringing charts, sag and tension tables including offset clipping, blow-out reports, structure and conductor usage reports, optimum spotting report and ground clearance report.

2.4.5 For sag and tension calculations, the "equivalent span" method shall be used. In calculating the sags and tensions, allowance shall be made for the elasticity and coefficients of expansion of the conductor materials. The operating temperature ranges and load conditions specified elsewhere in this Specification shall apply.

2.4.6 As part of the design process, the Contractor shall ensure that no part of the transmission line (towers, foundation, earthing, etc.) lies outside of the servitude, assuming maximum conductor swing conditions and maximum sag, and taking the required electrical clearances into consideration. Furthermore, in order to avoid uplift at suspension points, the Contractor shall ensure that, under the assumed conditions of minimum temperature without wind, the weight carried by any suspension insulator set shall not be less than 12.5 % of the total weight of the corresponding line conductor included in the two adjacent spans.

2.4.7 Any alterations to the overhead line required to obtain the above requirements and specified clearances and statutory requirements will be the responsibility of the Contractor and for his cost.

2.4.8 All designs and the profile sheets shall be reviewed in detail and signed off by the Contractor's Professional Engineer who holds a valid professional registration with the Engineering Council of South Africa.

2.5 Tower position pegging during design

2.5.1 The Contractor's registered Professional Surveyor shall peg all tower positions after the design is done to ascertain suitability of the location. The Employer's Engineer and/or Representative and Contractor shall visit each location and confirm the suitability, or agree on any relocation that may be necessary.

2.5.2 Should tower positions change, the tower spotting will be redone for the affected portion of the line, and the new tower positions pegged, and confirmed.

2.6 Profile sheets

2.6.1 Profile sheets generated by PLS-CADD shall indicate the location of towers and all relevant information along the line route. Each profile sheet shall include a strip plan, longitudinal and vertical sections and any other information which is necessary.

2.6.2 Suitable scales, in agreement with and subject to the approval of the Employer's Engineer, shall be selected to ensure all information is clearly visible in printed format. The default profile sheet shall be size A3 with scales as per the Employer's Engineer, unless otherwise specified.

2.6.3 On the strip plan the centre line of the overhead line shall be represented by a thick line at the bottom of the profile sheet running continuously between angle points or terminal points and all line deviation angles shall be indicated. The strip plan shall show all relevant information about the landscape such as fences, roads, tracks, rivers, watercourses, pipelines, telecommunication circuits, power lines, railway lines, dwellings and any other obstructions. All above mentioned features shall be accurately shown on a 30 m wide strip centred on the centre line. Any particular features such as power lines or tall objects or structures which fall within 50 m from the centre line shall also be indicated on the strip plan. In the case of power lines, roads and telephone circuits, the angle of crossing and the width of the feature to be crossed shall be indicated. Bush shall be identified by referring to the density of the vegetation, i.e. scattered, light, medium, dense bush or cultivated land. Soft sand, marsh or flooded ground shall also be indicated.

2.6.4 The longitudinal profile shall be drawn above the plan and shall correlate with features on the strip plan. An arbitrary datum may be used. The ground profile shall indicate the elevation above the selected datum and shall include two lines associated with the datum, the first and uppermost giving the chainage increasing along the line route between bend points and the second and lower line shall contain a running chainage continues between start and finish of the line. Elevations shall be recorded above the chainage.

2.6.5 Slide slopes shall be indicated throughout the entire length of the line. Where the transverse ground slope exceeds 1 in 10, levels up to distance of 10 m from the centre line shall be indicated in a dotted line on the longitudinal profile.

2.6.6 At crossing of overhead lines and telephone lines where the line being surveyed crosses between two supports, the height of the conductor to be crossed shall be the imaginary straight line connecting the uppermost attachment point of the supports and not the actual height of the conductors at the crossing point. Each crossing support shall be indicated on the profile section showing conductors, insulators and earthwire. The height of the uppermost attachment of the support shall be accurately measured from the elevation datum.

2.6.7 At railway crossings the following shall be recorded:

(1) At electrified railway crossing the height of the structure supporting the overhead conductor.

(2) At non-electrified crossings the height of the rail.

(3) Distance from crossing point to nearest railway identification mark (i.e. numbered railway telegraph pole, a ground distance marker or other identifiable feature).

2.6.8 The profile sheet shall indicate the following information adjacent to each structure: Manufacturer's tower code, tower classification, span ahead, structure number, structure position, structure type, ground elevation, attachment height of lowest conductor, wind span, max and min weight span.

2.6.9 The profile sheets (including the strip plans) shall be supplied in digital CAD and *.pdf format.

3.0 Foundations

3.1 General

3.1.1 The Contractor shall be responsible for the complete design of the foundations and for ensuring that the sub-soil at each foundation locations is suitable to withstand the design loading which will be imposed on it by the foundation and shall be responsible for any subsistence or failure of foundations due to insufficient examination or investigation of the soil conditions, insufficient foundation design or inadequate foundation installation. A suitably experienced Professional Civil Engineer, registered with the Engineering Council of South Africa, duly authorized to do so on behalf of the Contractor, shall check and assume responsibility for all foundation designs and drawings and shall sign all drawings accordingly. All foundation design loads are to be shown on the relevant foundation drawings.

3.1.2 The cost for the soil investigation and foundation design, including any associated tower position pegging or surveying shall be included in the price of the foundations, unless allowance is made in the **Price Schedules (Bill of Quantities)** with unit rates or as a reimbursable expense, or a combination of both.

3.2 Normative references

Document No.	**Document Title**
SANS 121	Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods
SANS 282	Fabrication and bending of reinforced steel
SANS 878	Ready-mix concrete
SANS 920	Steel bars for concrete reinforcement
SANS 1200GE	Precast concrete (Structural)
SANS 1431	Weldable structural steels
SANS 1491-1	Portland Cement Extenders: Part 1: Ground granulated blast furnace slag
SANS 1491-2	Portland Cement Extenders: Part 2: Fly ash
SANS 1491-3	Portland Cement Extenders: Part 3: Silica Fume
SANS 5862-1	Concrete tests - Consistence of freshly mixed concrete – Slump test
SANS 5863	Concrete tests – Compressive strength of hardened concrete
SANS 10100-1	The structural use of concrete. Part 1: Design
SANS 10100-2	The structural use of concrete. Part 2: Materials and execution of work
SANS 10162-1	The structural use of steel. Part 1: Limit-state design of hot-rolled steelwork
SANS 10162-2	The structural use of steel. Part 2: Limit-state design of cold-formed steelwork

Document No.	Document Title
SANS 50197-1	Cement Part 1: Composition, specifications and conformity criteria for common cements
SANS 1083	Aggregates from natural resources – Aggregates for concrete
BS 4027	Specification for Sulphate resistant Portland cement
ASCE Standard 10-97	Design of Latticed Steel Transmission Structures (Previously known as ASCE Manual 52)
OHS Act, 85 of 1993, as amended	Occupational Health and Safety Act 85 of 1993, as amended, incorporating the 2014 Construction Regulations. Published by South African Government Press, under auspices of the Department of Labour
SANS 10280-1	Overhead power lines for conditions prevailing in South Africa, Part 1: Safety

3.3 Rock and soil classification

3.3.1 The following rock and soil classification system shall be used:

Soil Type	Description
Hard Rock	Hard to very hard solid or moderately fractured continuous rock.
Soft Rock	Weathered or decomposed very soft continuous rock and rock of any other classification which does not satisfy the requirements for classification as hard rock.
Type 1 Soils	Competent soil with equal or better consistency than would be encountered in stiff cohesive soils or dense cohesionless soils above the water table. This soil must have a broad balanced texture (constituent particle sizes) with high average combinations of undrained shear strength and internal angle of friction, with minimum values of 80 kN/m^2 and 30 ° respectively. The minimum natural specific weight shall be not less than 18 kN/m^3.
Type 2 Soils	A less competent soil than type 1, with equal or weaker consistency than encountered in firm to stiff swelling cohesive soils, or dry poorly graded loose to medium dense cohesionless soils above the water table. The minimum undrained shear strength shall be 40 kN/m^2. The minimum natural specific weight shall be not less than 16 kN/m^3.
Type 3 Soils	Dry, loose, cohesionless soil or very soft to soft cohesive soil.
Type 4 Soils	Submerged cohesionless and cohesive soils. This includes all soils below the permanent water table, including soils below a re-occurring perched water table, or permeable soils in low-lying areas subject to confirmed seasonal flooding.

3.4 Soil investigation and design parameters

3.4.1 The minimum soil investigation requirement shall be the excavation of a test pit next to each set of foundations for a tower, to allow for the in-situ inspection of the soil, recording thereof on a soil profile

log sheet and the type assessment. The soil investigation on site shall include bearing, shear vane and penetration tests.

3.4.2 The test pit shall be excavated outside the zone of influence of the appropriate foundation and shall be to a depth of the lesser of 4 m and 1.2 times the depth of the proposed foundation.

3.4.3 All soil investigations shall be done in the presence of the Employer's duly authorized Representative.

3.4.4 The assessment of the soil shall be conducted by a suitably experienced Professional Geologist, registered with the relevant recognized body for such professionals, duly authorized and on behalf of the Contractor.

3.4.5 Should the soil conditions vary for the foundation positions of the different legs of the same tower, separate soil investigations shall be done to ensure that the correct foundation is selected for the in-situ soil conditions at each location.

3.4.6 Where further detailed analysis and tests are required, these shall be conducted upon the approval of the Employer's Engineer.

3.4.7 Any deep boring required shall be conducted by an approved Subcontractor as per unit rates quoted in the **Price Schedules (Bill of Quantities)**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

3.4.8 Backfilling shall be done with layered compaction to restore the ground to its normal state. The Contractor shall be responsible to rehabilitate the ground to its original form- this can be done after the construction of foundation provided that no soil erosion occurs prior to foundation construction.

3.4.9 Soil nominations shall be done well in advance of the actual foundation construction in order to ensure that there is no unnecessary delay of the construction programme.

3.4.10 Once the soil nomination for a tower has been done, these results must be forwarded to the Contractor's registered Professional Engineer in order to design the foundation, taking into consideration the soil conditions and tower loads. The Contractor shall forward both the soil investigation results and report (including a digital colour photograph of each of the soil investigation trenches) together with the proposed foundation selections (i.e. such as Pad and column for Type 2 soil, etc.) and the Contractor's foundation designs to the Employer's Engineer to evaluate and accept prior to starting with the actual foundation construction.

3.4.11 In addition to the minimum soil/rock investigation requirements, additional tests shall be carried out by the Contractor where further clarification is required for the correct identification of the soil or rock type. These tests shall be conducted in accordance with accepted, good geotechnical engineering practices. The tests shall be performed at the worst possible soil condition expected at a particular foundation site (e.g. soaked conditions due to seasonal or continuous flooding if applicable).

3.4.12 The following geotechnical design parameters shall be used:

Parameter	**UOM**	**Hard Rock**	**Soft Rock**	**Soil Type 1**	**Soil Type 2**	**Soil Type 3**	**Soil Type 4**
Maximum soil bearing pressure	kPa	2000	800	300	150	100	50
Maximum toe bearing pressure	kPa	2000	800	375	200	125	65
Frustum angle (suspension towers)	Degrees	45	37	30	20	0	0
Frustum angle (tension towers)	Degrees	45	37	25	15	0	0

Parameter	UOM	Hard Rock	Soft Rock	Soil Type 1	Soil Type 2	Soil Type 3	Soil Type 4
Undrained shear strength (Interface friction concrete to soil)	kN/m^2	300	135	80	40	0	0
Density of backfill	kg/m^3	-	-	1800	1600	1400	1000
Density of reinforced concrete	kg/m^3	-	-	2400	2400	2400	2400

3.4.13 List of soil tests:

(1) Standard Penetration Tests or Dutch Cone Penetrometer tests

(2) Visual classification of soils.

(3) Determination of present and probable water table level.

(4) Laboratory and/or site tests to determine soil friction angles and cohesion values.

(5) Laboratory tests to determine stress-strain modules of soils and rock.

(6) Laboratory and/or site tests to determine soil unit weights.

(7) Laboratory and/or on-site tests to determine the soil texture i.e. whether the soil is predominantly clay, silt, sand or gravel.

(8) Continuous rock cores with recovery values and drilling times.

The standard penetration tests and recovery of soil samples shall be obtained in each soil strata encountered or at 1.0 m intervals, whichever is less. Rock cores shall extend a minimum of 3.5 m into sound rock.

3.5 Foundation design loads

3.5.1 The ultimate simultaneous tower design loads shall be used for foundation design purposes, i.e. maximum combinations of compression, uplift and horizontal shear forces associated with the working and unbalanced loads and factors of safety.

3.5.2 Tower foundations shall be designed with a factor of safety against overturning or uprooting of not less than:

(1) Normal working loading condition: 2.5

(2) Unbalanced loading condition: 1.5

3.5.3 The foundation loads calculated shall be factored upwards for foundation design purposes by a load factor equal to **1.2 for lattice steel self-support type towers**. In addition to the above, the foundations shall be designed for the most critical/ severe cases that would result from the occurrence of the maximum permissible construction tolerance situations. Taking all of these loadings into account, the design safety factors shall apply.

3.5.4 All foundation design loads are to be shown on the drawing for each particular foundation and soil type. This is a hold point and the Contractor may not start with the foundation construction before the Employer has accepted the proposed foundation selection as well as the Contractor's foundation designs.

3.6 Foundation systems

3.6.1 Standard foundations predominantly utilised by the Employer are the reinforced concrete pad and pier type. Drilled pile and rock anchor foundations have been used on a few lines. Drilled pile and/or rock anchor foundations shall be used on the project only if specified in the **Scope of Work and/or Price Schedules (Bill of Quantities),** or subject to specific approval by the Employer's Engineer.

3.6.2 Foundation prices for each soil or rock type applicable to each tower/ structure type shall be quoted in the **Price Schedules** per foundation, per set of foundations for the tower or structure, and/or per activity for the foundation, as may be specified in the **Scope of Work** and/or **Price Schedules**.

3.6.3 Only with the specific permission of the Employer's Engineer may more than one design per rock or soil type of any foundation system for a particular tower type be utilized.

3.6.4 Before foundation excavation commences, the Contractor shall submit to the Employer's Engineer, drawings and relevant design calculations of all the proposed foundations intended for use. Acceptance by the Employer's Engineer does not relieve the Contractor of his responsibility for the adequacy of the design, dimensions and details.

3.6.5 All steelwork in concrete shall be suitably galvanized. Stubs and cleats shall be installed with approved keying arrangements.

3.6.6 All concrete foundations, including any capping shall protrude from the natural ground level (and not the levelled section around a foundation). For pier and pad foundations, the pier shall protrude from the ground by at least 500 mm but not more than 650 mm. For pile-cap foundations, or any other foundation that has a large capping as part of the foundation design, this capping shall protrude not more than 150 mm from the natural ground measure from the highest ground in contact with the capping, and a separate full strength pier (with rebar) shall be constructed on top of the capping for encasement of the steel. This separate pier shall have a minimum cross-section area of 500 x 500 and shall be constructed and protrude from the natural ground level by at least 500 mm but not more than 650 mm. The upper surface of all concrete foundation/ capping shall be steeply sloped (giving the centre an additional height of not less than 50 mm) so as to allow for water run-off. Furthermore. the concrete around any steel and/or bracing protruding out of the concrete shall be steeply sloped to ensure water run-off. The capping shall be of the same quality and property (strength) as the concrete used for the actual foundation. If cast separately, the existing uncured, partially cured or fully cured concrete shall be thoroughly cleaned (all residue and loose material removed) and the new concrete shall be keyed onto the stub and pier or pile cap.

3.6.7 The first 500 mm of the stub and tower steel which protrudes from the foundation cap, the exposed foundation concrete, and the foundation concrete down to at least 500 mm below ground level, shall be painted with a suitable primer and epoxy coaltar or other approved paint to a total dry film thickness of not less than 300 µm. No part of the structural steelwork of the tower shall be buried or come into contact with the soil.

3.6.8 For pad and pier foundations:

(1) The maximum bearing pressure due to vertical compressive loads, plus the mass of the foundation, less the mass of the soil displaced by the foundation shall not exceed the **geotechnical design parameter values**.

(2) The foundation shall be designed to resist the vertical uplift load by means of the mass of the foundation plus the net mass of the soil frustum acting from the bottom of the foundation base.

(3) The foundation shall be designed to resist the horizontal shear forces by determining the lateral resistance of the backfill on the various sections of the foundation by multiplying the backfill soil weight density by the depth of that section. The maximum soil toe bearing pressure shall not exceed the **geotechnical design parameter values**.

(4) The maximum angle between the base and sides of the foundations for uplift conditions shall be 70 °.

(5) The structural steel shall be firmly keyed into the concrete by means of adhesion between steel and concrete and bolted-on cleats. A maximum of 50 % of the maximum leg load, either in tension or compression, may be transferred from the steel stub angle to the concrete, and neglecting the top 500 mm of the pier. The balance of the load shall be transferred by means of bolted-on cleats.

3.6.9 For drilled pile foundations:

(1) The Contractor shall have the necessary equipment for, and personnel knowledgeable and experienced in, the evaluation and construction of this type of foundations.

(2) These foundations shall consist of vertical piles with a minimum diameter of 300 mm each, and with a minimum of two piles per foundation for suspension towers, and a minimum of four piles per foundation for strain towers.

(3) The piles shall be connected to the tower steel by means of a reinforced concrete pile cap.

(4) The piles and pile cap shall be designed for the maximum combinations of uplift and compression loadings, and the total horizontal base shears associated with the vertical loadings, including leg shear. Lateral load design bending moments shall be calculated taking into account possible plastic soil deformation.

(5) The interface “skin” friction values that are used in the design shall not exceed **geotechnical design parameter values or** 80% of the ultimate friction determined from appropriate soil tests.

(6) The piles shall be adequately reinforced for their entire length in order to resist the applied axial and bending forces and sufficient reinforcing hoops shall be provided to support the vertical reinforcing.

(7) The structural steel shall be firmly keyed into the concrete by means of adhesion between steel and concrete and bolted-on cleats.

(8) Allowance shall be made for all possible group effects when two or more piles are used in a group.

(9) Inclined rock anchors/piles need specific approval from the Employer’s Engineer. Rock anchors or piles shall not carry any shear loads. The shear loads shall be transferred to the rock or soil by the anchor/pile cap. The anchor/pile cap shall handle the total horizontal base shear force. For design purposes the re-compacted excavated soil on top of the cap shall not contribute to the horizontal resistance of the cap. The projection of a rock anchor foundation shall at least be 650 mm above NGL, achieved by the capping or combination of the capping and pier above the capping. The minimum penetration depth of the anchor cap into the rock shall be 150 mm into sound rock over its full base area.

3.6.10 For soft and hard rock anchor foundations:

(1) The design parameters used for soft and hard rock anchor foundations shall be compiled and approved by a suitably experience Professional Civil Engineer, registered with the Engineering Council of South Africa, duly authorized to do so on behalf of the Contractor.

(2) Rock anchors shall have a minimum diameter of 100 mm and shall protrude at least 1100 mm into the sound rock. Smaller anchor diameters have to be approved by the Employer’s Engineer.

(3) The allowable lateral pressure on the leading face of the rock anchor cap, together with the friction on the two side faces in the rock, shall be less than the **geotechnical design parameter values** or 80% of the permissible value determined from appropriate tests.

3.6.11 For special foundations:

(1) Where ground conditions are unsuitable for the installation of standard foundations, the Contractor will be required to make arrangements to provide special piled or other special foundations. The Employer's Engineer may require that such specialized foundation work be carried out by an approved Subcontractor. Special foundations shall be constructed using applicable unit rates quoted in the **Price Schedules** that are deemed to relevant and suitable for the required activities, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

3.6.12 Pile/Anchor tests

(1) The Contractor shall allow for the testing of two separate piles in each of the soil conditions for which these have been designed. Pile tests, if so required by the Employer's Engineer, are to be successfully tested to the Employer's Engineer's satisfaction prior to the construction of cast-in-situ pile foundations.

(2) The test pile/anchor shall not be part of a final foundation.

(3) The purpose of the test is to verify the concrete/soil or grout rock frictional resistance values.

(4) The Contractor shall prepare the test procedure and supply all equipment and personnel to perform the tests. All pile tests shall be conducted to failure of the pile. The test procedure shall be submitted to the Employer's Engineer for acceptance prior to the tests.

(5) The tests shall be conducted in the presence of the Employer's Engineer or his Representative.

(6) Upon completion of the test, the pile shall be removed by the Contractor for examination, and properly disposed of, or cut-off at least 600 mm below ground level and backfilled, or as directed by the Employer's Engineer.

3.7 Design criteria for reinforced concrete

3.7.1 The foundations shall be designed for a concrete strength of 25 MPa. The cement shall comply with SANS 1491. Where the environment is aggressive to this cement, sulphate resistant cement to BS 4027 may be used where approved by the Employer's Engineer.

3.7.2 The maximum ultimate stresses allowable in concrete for foundation design shall be as follows:

Type of Stress	**Stress Values**
Tensile stress due to bending	2.0 MPa
Bond stress, galvanized steel/concrete	1.0 MPa
Bearing stress (ordinary Portland cement)	21.0 MPa
Punching shear stress	7.0 MPa
Diagonal shear stress	4.3 MPa

The minimum proportion of stub load to be designed for in the design of stub cleats shall be 50%.

3.7.3 All main reinforcing steel shall comply with SABS 920, Type C, Class 2, Grade II, hot rolled deformed bars with a minimum yield stress of 450 MPa. The minimum bar size utilized shall be 10 mm. All secondary reinforcing for stirrups, hoops and spirals, shall as a minimum conform to SABS 920, Type A, hot-rolled bars of plain cross-section of mild steel with a minimum yield stress of 250 MPa.

3.7.4 The minimum concrete cover for reinforcing steel including hoops, after taking into consideration construction tolerance, shall be 75 mm. Where spacers or cover blocks are used to support the lower layers of reinforcing, these shall be at least 100 mm thick to make allowance for the uneven ground surface. Concrete cover block shall be a minimum 25 MPa strength when used. The spacers/ cover blocks shall be non-porous. The Employer's Engineer shall reserve the right to have samples of these blocks tested. Should the blocks not meet the minimum specifications, the cost of the tests and the resources used shall be for the Contractor's account, deductible from the **Price Schedules**.

3.7.5 The minimum concrete cover for steelwork (stubs and keys) shall be 80 mm.

3.7.6 Adjustable leg stubs should be used with pad and pier foundations in order to ensure that the K-point on all leg stubs is at least 650 mm above the natural ground level (NGL). Unless otherwise instructed by the Employer's Engineer, the concrete/ steel interface section of each leg stub that is protruding from the concrete shall be coated, prior to concreting, by means of an organic or inorganic zinc-rich primer, for 500 mm above the concrete cap position to 400 mm below the concrete cap position. The proposed paint system shall be submitted for approval to the Employer's Engineer before application. Before painting, the hot dip galvanized steel shall be cleaned with approved galvanized iron cleaner, water rinsed and allowed to dry. Painting of the stub section shall take place within two to four hours of the preparation process.

3.7.7 The spacing and levels of the leg stubs shall be checked and corrected prior to and after concreting in order to ensure the correct alignment of the leg stubs, and without having to force any tower members to their required positions during tower erection.

3.7.8 All concrete corners (vertical and horizontal) from 150 mm below ground level and any position above ground level shall be chamfered by at least 50 mm.

3.7.9 Unless otherwise approved, tower erection may only start fourteen days after the casting of the concrete in order for the concrete to gain sufficient structural strength. Shorter periods may be approved by the Employer's Engineer, provided special precautions are taken (i.e. the use of fast curing cement/ concrete).

4.0 Tower

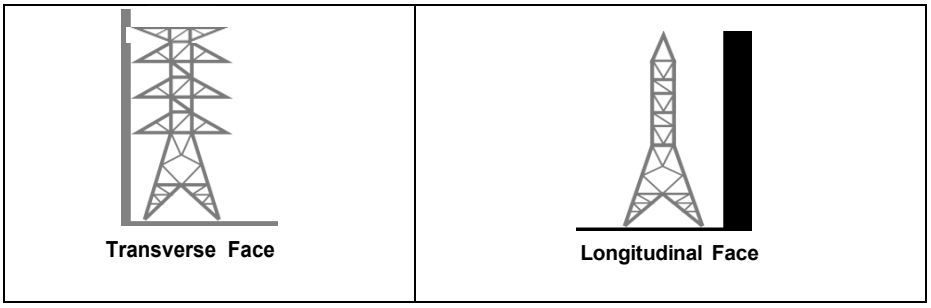
4.1 General

4.1.1 Towers shall be of the steel lattice, self-supporting, broad based type without struts or stays, mounted on reinforced concrete foundations, or other such foundations as may be approved by the Employer's Engineer.

4.1.2 Towers shall be designed to support the phase and earth conductors, all associated insulators, fittings and hardware under the conditions and with the safety factors specified, and compliance to SANS 10280-1.

4.1.3 Double circuit towers shall be designed so that they can be strung and operated with one circuit and two earth wires only. All specified and mandatory factors of safety and design criteria shall apply under this condition.

4.1.4 Tower face designation is as per drawing below.



4.2 Normative references

Standard	Description
OHS Act, 85 of 1993, as amended	Occupational Health and Safety Act 85 of 1993, as amended, incorporating the 2014 Construction Regulations. Published by South African Government Press, under auspices of the Department of Labour
SANS 675	Zinc-coated fencing wire
SANS 10280-1	Overheads power lines for conditions prevailing in South Africa. Published by the South African Bureau of Standards.
SANS 50025 / EN10025	Hot rolled products of structural steel. Published by the South African Bureau of Standards
SANS 1431	Weldable structural steel
SANS 121 /ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles-Specifications and test methods. Published by the South African Bureau of Standards
SANS 182-5	Zinc coated steel wire for conductors and stays
ASCE Standard 10	Design of Latticed Steel Transmission Structures. Published by the American Society of Civil Engineers.

DIN 7990	Steel hexagon head bolts for structural steel bolting, for supply with hexagon nuts.
IEC 60652	Loading tests on overhead line towers

4.3 Conductor spacing and attachment

4.3.1 The table below gives typical spacing. Should there be a deviation from these spacing, the Bidder shall indicate this deviation in his bid and provide reasons for the deviation. The final decision on whether to accept or reject other design spacing shall be made by the Employer's Engineer.

Item	Arrangement	Typical Spacing	
		132 kV	275 kV
1	Double circuit towers shall have their phase conductors in vertical formation. There shall be an earth conductor above the phase conductors of each circuit. Horizontal spacing between conductors of different circuits shall be approximately:	8 m	12.4 m
2	Spacing of phase conductors of the same circuit:	4 m	7.5 m
3	Spacing of phase and earth conductors of the same circuit:	4 m	7.0 m

4.3.2 The preferred maximum angle from the vertical of the line from the highest phase conductor to earth conductor of a circuit shall be 15 ° for 132 kV and 17 ° for 275 kV, unless specified otherwise in the **Technical (Returnable) Schedules** and/or **Drawings issued**.

4.3.3 Single circuit towers shall have their phase conductors in horizontal or delta formation. There shall be two earth conductors mounted above the phase conductors for the horizontal configuration and one earth conductor for the delta configuration.

4.3.4 Tower dimensions shall be provided by the Contractor in the **Technical (Returnable) Schedules**.

4.3.5 All insulator sets and associated fittings shall be attached to the tower cross-arms by shackles. Provision shall be made for the attachment of conductor erection and maintenance equipment to all cross-arms.

4.3.6 Earth conductor and/or OPGW conductor shall be attached to the towers by means of suspension insulators and clamps at suspension towers and tension insulators and clamps at tension towers. The earth conductors/ OPGW shall be bonded to the tower steelwork at points directed by the Employer's Engineer. All towers (both suspension and tension types) shall be provided with earth bonding points on each circuit side, on the earth-peak and waist/cage, where a bolt with lug or clamp can be fitted, and those on waist/cage shall be visible from ground level.

4.4 Standard towers

4.4.1 Double circuit towers shall normally be of the following standard types and designations:

Tower Description	Tower type/ Designation	Line Route Deviation Range and Tower Positioning Details	Insulator Type
Double circuit straight line	D	0° to 2°	Suspension
Double circuit 30° angle	D30	2° to 30°	Tension
Double circuit 40° angle	D40	2° to 40°	Tension
Double circuit 60° angle	D60	30° to 60° if the series has a D30 or 40° to 60° if the series has a D40	Tension
Double circuit 90° angle	D90	40° to 90° if the series has a D40 and not a D60 or 60° to 90° if the series has a D60	Tension
Double circuit terminal	DT	• For the case where the angle between the transmission line conductor and the normal to the length of the station does not exceed 45°. A normal is an imaginary line perpendicular to the length of the station and to the plane of the landing span gantries. • The tower can then be positioned such that the plane of the tower cross-arms is parallel to the length of the station and to the plane of the landing span gantries. This will allow the transmission line conductor to terminate on the tower at any angle up to but not exceeded 45° from the tower centre line normal to the length of the station.	Tension
Double circuit 90° terminal	DT90	• For the case where the angle between the transmission line conductor and the normal to the length of the station exceeds 45°. • The tower can then be positioned such that the plane of the tower cross-arms is at an angle of 45° to the length of the station and to the plane of the landing span gantries. This “tower orientation” angle could be made less than 45° if more suitable for the site condition, such as making the plane of the cross-arms be on the bisector of the line conductors and the landing span conductors.	Tension

Tower designations shall be prefixed with the number of conductors per phase bundle, e.g. 2D30 for twin bundle conductor on double circuit 30° angle tower.

4.4.2 Single circuit towers shall normally be of the following standard types and designations:

Tower Description	Tower type/ Designation	Line Route Deviation Range and Tower Positioning Details	Insulator Type
Single circuit straight line	S	0° to 2°	Suspension
Single circuit 30° angle	S30	2° to 30°	Tension
Single circuit 40° angle	S40	2° to 40°	Tension
Single circuit 60° angle	S60	30° to 60° if the series has a S30 or 40° to 60° if the series has a S40	Tension
Single circuit 90° angle	S90	40° to 90° if the series has a S40 and does not a S60 or 60° to 90° if the series has a S60	Tension
Single circuit terminal	ST	• For the case where the angle between the transmission line conductor and the normal to the length of the station does not exceed 45°. A normal is an imaginary line perpendicular to the length of the station and to the plane of the landing span gantries. • The tower can then be positioned such that the plane of the tower cross-arms is parallel to the length of the station and to the plane of the landing span gantries. This will allow the transmission line conductor to terminate on the tower at any angle up to but not exceeded 45° from the tower centre line normal to the length of the station.	Tension
Single circuit 90° terminal	ST90	• For the case where the angle between the transmission line conductor and the normal to the length of the station exceeds 45°. • The tower can then be positioned such that the plane of the tower cross-arms is at an angle of 45° to the length of the station and to the plane of the landing span gantries. This “tower orientation” angle could be made less than 45° if more suitable for the site condition, such as making the plane of the cross-arms be on the bisector of the line conductors and the landing span conductors.	Tension

Tower designations shall be prefixed with the number of conductors per phase bundle, e.g. 2S30 for twin bundle conductor on single circuit 30° angle tower.

4.4.3 With the plane of the cross-arms being up to 45° to the plane of the landing gantry/ gantries, the landing spans shall be erected with substantially reduced tensions which shall be assumed to be zero for the purpose of tower design and shall normally be supported by light duty tension insulator sets.

4.4.4 Towers shall be designed so that they may be raised by extensions of 3 m, 6 m, 9 m (3 m only for right angle and terminal towers). Towers shall also be provided with independent single-leg extension

for steep sloping ground to adjust the standard leg height by -2 m to +4 m or greater in 0.5m increments. These extensions (body and leg) shall be so designed so that the maximum extended towers with their foundations comply with all the specified requirements of the standard towers and foundations. A further suffix of "E" followed by the body extension height in metres will follow the tower designation for extended towers, e.g. 2D30E3 for twin bundle conductor on double circuit 30° angle tower with 3 m body extension. There is no suffix for the leg extensions as the legs can be different for an individual tower according to the ground conditions.

4.4.5 Special towers, together with their foundations, and special extensions and special parts for standard towers shall be provided where required and shall be of an approved design. These will be paid for at the unit rates per metric ton (to the nearest kilogram assuming a density of 7850 kg/m^3) quoted in the **Price Schedules (Bill of Quantities),** alternatively as a reimbursable expense where rates do not exist.

4.4.6 The type of tower and extension used at each position shall be to the approval of the Employer's Engineer.

4.5 Span lengths

4.5.1 "Span length" shall be taken to mean the horizontal distance between the centre lines of adjacent towers.

4.5.2 Unless otherwise indicated in the **Technical (Returnable) Schedules**, the design span lengths, and weight and wind spans, shall be as per table below:

Item	**Description**	**132 kV Towers/ Line**	**275 kV Towers/ Line**
1	**Standard design span lengths** for Single/ Twin Elm phase conductor/s and Oak earthwire and Oak equivalent OPGW.	300 m	N/A
2	**Standard design span lengths** for Single/ Twin Yew phase conductor/s and Elm earthwire and Elm equivalent OPGW.	300 m	365 m
3	Tower weight span minimum capacity	600 m	730 m
4	Tower wind span minimum capacity	330 m	402 m
5	Tower capable to carry conductor where single span length is up to	510 m	620 m

These shall be the span lengths on which all standard tower heights, assuming level ground, shall be based.

4.5.3 Towers shall be designed to have the capacity to carry conductors where:

(1) the sum of the two adjacent spans may total 2.2 times the standard span length, which can be applied where the ground profiles are favourable.

(2) any one span may be up to 1.7 times the standard span length.

(3) the combined back and ahead weight span may be 200% of the standard weight span.

4.5.4 Where the ground profiles are favourable, angle towers may, at the discretion of the Employer's Engineer, be used at reduced angles of deviation, but with the sum of the two adjacent spans exceeding the figures stated above, provided that the factors of safety specified herein are obtained and the servitude is sufficient to allow for the corresponding conductor side swing.

4.6 Electrical clearances

4.6.1 Statutory clearances

4.6.1.1 The minimum electrical clearances are stated in the table below. Vertical clearances shall be obtained based on the assumed conditions corresponding to the still air sag at the maximum operating temperature of the line conductors as stated in the **Technical (Returnable) Schedule,** and with any angle of swing of the line conductors from the vertical between zero and the maximum angle as stated in the **Technical (Returnable) Schedule**, assuming maximum sag. Horizontal clearances shall be obtained under the conditions laid down in the OHS Act, as amended.

Item	**Situation**	**Minimum clearance from the line conductor or live fitting operating at**	
		132 kV	**275 kV**
1	Ground clearance all areas	6.3 m	7.4 m
2	Roads in townships and proclaimed roads, railways	7.5 m	8.6 m
3	To all buildings, poles, structures not part of the power lines and vegetation	3.8 m	4.9 m
4	To communication lines and between power lines	2.0 m	3.1 m
5	Railway crossings:		
	(a) Non-electrified lines to rail level	10.9 m	11.8 m
	(b) Electrified lines- Overhead track equipment other than earth wires	3.3 m	5.0 m
	(c) Electrified lines- Overhead track equipment earth wire	3.3 m	5.0 m

4.6.1.2 Where the power line crosses over another power line or over a communication line, (e.g. telephone line), clearances shall be provided in accordance the Occupational Health and Safety Act, No. 85 of 1993 as amended, in particular with SANS 10280-1.Where there is a variance between the values indicated in this specification and SANS 10280-1 or any other national regulation, the most stringent and onerous of the conflicting regulations shall apply.

4.6.1.3 The minimum clearances for 132 kV will allow the conductor to be operated at a final temperature of 75°C. However, the design process shall also be carried out for a final conductor temperature of 90°C to identify the areas of constraints should the Employer consider operating the line at this higher value. The Contractor shall indicate which additional structures and/or leg/body extensions may be necessary to accommodate this condition.

4.6.1.4 The minimum clearances for 275 kV are based on a final conductor temperature of 75°C.

4.6.1.5 In addition to above mentioned clearances, a margin of 1.0 m to ground shall be used during profiling; (0.5 m for survey tolerance and 0.5 m as design buffer).

4.6.2 Tower top clearances

4.6.2.1 Towers shall be designed to meet minimum electrical clearance between any live metal and tower steelwork under various climatic conditions as indicated below.

4.6.2.2 Suspension tower minimum clearances

Condition and swing angle	**Minimum clearance from live metal to tower steelwork**	
	132 kV tower	**275 kV tower**
Still air where phase insulator swing angle is 0°	1.50 m	2.35 m
Slight wind where phase insulator swing angle is 10°	1.50 m	2.35 m
Specified maximum wind loading where phase insulator swing angle is 45°	1.30 m	2.10 m
Specified maximum wind loading where phase insulator swing angle is 60°	0.35 m	0.70 m

The clearances listed above shall be met based on the assumption that the phase conductor may leave the suspension clamp at a (vertical departure) angle between 0° and 20° measured in the plane of the insulator string.

Earth wire suspension clamp unobstructed swing from vertical: 0 to 60°.

4.6.2.3 Tension tower minimum clearances

Condition and swing angle	**Minimum clearance from live metal to tower steelwork**	
	132 kV tower	**275 kV tower**
Still air where jumper swing angle is 0°	1.50 m	2.35 m
Slight wind where jumper swing angle is 5°	1.50 m	2.35 m
Specified maximum wind loading where jumper swing angle is 20°	1.30 m	2.10 m

Clearances shall also apply for a conductor with upward or downward departure angle of up to 15 degrees.

4.7 Conductor sag and tension limits

4.7.1 The tower shall have the full capability for the following conductor tensions:

Conductor condition	Phase conductor	Earthwire	OPGW
Maximum working tensions	2 x 40 % x UTS	40 % x UTS	40 % x UTS
Maximum still air tension @ 15°C	2 x 20 % x UTS	20 % x UTS	20 % x UTS
Conductor template temperature	75°C	75°C	75°C
Additionally, maximum working tension @ 15°C and max. wind as per SANS 10280-1	2 x 70 % of UTS	70 % of UTS	70 % of UTS
Initial condition at -5°C	C limit: 2 450 m	C limit: 2 750 m	To match EW

$C = H / g_c$ (in m)

where

g_c Unit weight of the conductor (N/m), and

H is the horizontal component of conductor tension (N).

4.7.2 Conductor sag and tension calculations shall be based on the following temperatures:

Minimum temperature of conductors and earth wire	-5°C
Everyday temperature	15°C
Templating temperature	75°C

Note: In the design process, check operating constraints for operation at 90°C at 132 kV.

4.8 Loads acting on towers based on legacy requirements

4.8.1 Basic legacy requirements

4.8.1.1 The legacy requirements applied factors of safety for tower designs. These requirements have been retained because this General Technical Specification caters for both existing and new power lines.

4.8.1.2 All possible tower heights with all combinations of body and leg extensions shall be considered in the design of a tower. A 30-degree ground slope shall be considered to determine all possible combinations of leg extensions. The most onerous conditions of various combinations of minimum and maximum line deviation angles, minimum and maximum weight spans, minimum and maximum wind spans, combined with minimum allowed weight span, shall be considered in the design of each tower type.

4.8.2 Factors of safety

4.8.2.1 Steel towers, gantries and foundation structures shall be designed with the following factors of safety, based on the elastic limit of tension members and on the crippling load of compression members, or on tower tests:

(1) Normal working loading condition: 2.5

(2) Unbalanced loading condition: 1.5

4.8.2.2 For double circuit towers, the above specified factors of safety shall be met, whether both circuits with both earth conductors are erected, or one circuit with both earth conductors are erected, and at any angle of deviation within the particular range specified.

4.8.3 Working loads

4.8.3.1 The assumed maximum simultaneous working loads on towers at their maximum angles of deviation and maximum span lengths (except as modified by the following assumed vertical and transverse loadings) shall be as indicated below.

4.8.3.2 Vertical loads:

(1) To allow for towers being at different levels, the vertical loads shall be assumed to include the dead weights of twice the standard design span length of the line and earth conductors and associated insulators, fittings and hardware. The weight span tower capacity shall be at least **200% of the standard span length** for both 132 kV and 275 kV applications.

(2) All tension towers shall be designed for a net uplift load acting at line and earth conductor attachments equal to one third of the respective maximum working tensions specified.

(3) For straight line towers, the weight carried by any suspension insulator set shall not be less than 12.5% of the tower weight span at minimum conductor temperature of -5°.

(4) Suitable wind/weight span ratio shall be employed to ensure suspension insulator swing does not exceed 60° under wind pressure of 575 Pa acting on conductor and insulator.

4.8.3.3 Transverse loads:

For the calculation of transverse loads, the following shall be taken into account:

(1) A wind pressure of 700 Pa perpendicular to the line, on 0.6 times the projected area of the line and earth conductors, over 110% of the standard design span. The maximum wind spans shall be **110% of the standard span length** for both 132 kV and 275 kV.

(2) The transverse horizontal resultants of the maximum line and earth conductor working tensions at the maximum deviation angle of the tower type.

(3) A wind pressure of 700 Pa on 1.5 times the projected area of the members of one face of the towers.

(4) All tower designs shall be checked for wind at 45° to the longitudinal axis.

(5) Straight line towers shall be checked for the combined case of ultimate transverse wind loads and minimum working vertical loads of standard design span.

4.8.3.4 Longitudinal terminal Load (on terminal towers only):

These shall be assumed to be the longitudinal components of the maximum line and earth conductor working tensions.

4.8.3.5 Additional loads:

Towers and foundations shall be designed to allow for additional loads to which the towers may be subjected to during erection of the tower members, conductors or insulators or the maintenance thereof.

4.8.4 Unbalanced loads

4.8.4.1 Towers shall be designed to withstand unbalanced load conditions as required below.

4.8.4.2 Unbalanced load conditions for straight line (suspension) towers:

For suspension towers it is assumed that any one attachment point of the tower will be subject to the following unbalanced loads due to the breakage of a conductor associated with that attachment point (the remaining attachments will be subject to their maximum working loads):

(1) Transverse load due to wind: 75% of maximum wind span.

(2) Vertical load due to span weight: 75% of maximum weight span.

(3) Longitudinal load due to conductor tension: maximum conductor tension in still at 15°C.

The longitudinal load for twin conductor configurations is the maximum conductor tension in still air at 15°C for one conductor only, i.e. only one of the two conductor breaks.

4.8.4.3 Unbalanced load conditions for angle (tension) towers:

For tension towers it is assumed that any two cross-arms of the tower will be subject to the following unbalanced loads due to the breakage of conductors (or stringing procedure) associated with one side of those cross-arms (the remaining cross-arms will be subject to their maximum working loads):

(1) Transverse load due to wind: 75% of maximum wind span.

(2) Transverse load due to deviation angle: 50% of load due to normal maximum deviation.

(3) Vertical load due to span weight: 75% of maximum weight span.

(4) Longitudinal load due to conductor tension: maximum working tension of conductor in still air at 15°C, (both breakages in the same direction).

The longitudinal load for twin conductor configurations is the maximum working tension of the conductor in still air at 15°C for both conductors, i.e. both phase conductors break for two different cross-arms and in the same direction.

4.8.4.4 The tower designs shall comply with the above conditions without restriction to the spans in which the breakages may occur.

4.9 Loads acting on the tower as per SANS 10280-1

4.9.1 General

4.9.1.1 New towers shall also be designed to withstand wind, construction and maintenance, security and co-incident tension and vertical loads as described in SANS 10280-1 The loads acting on the towers shall be determined according to the DETAILED METHOD indicated in SANS 10280-1.

4.9.1.2 All possible tower heights with all combinations of body and leg extensions shall be considered in the design of a tower. A 30-degree ground slope shall be considered to determine all possible combinations of leg extensions. The most onerous conditions of various combinations of minimum and maximum line deviation angles, minimum and maximum weight spans, minimum and maximum wind spans, combined with minimum allowed weight span, shall be considered in the design of each tower type.

4.9.2 Wind loads

4.9.2.1 The basic parameters for determining wind loads acting on towers are indicated below:

Reliability level	Minimum shall be 1 (up to and including 132 kV) and 2 (for > 132 kV to ≤ 400 kV), unless higher values are specified in the **Technical (Returnable) Schedules.**
Terrain category	B (Open country with few obstacles)
Reference (10 min) wind speed (V_{RB}) at 10 m of height	29 m/s
Combination of wind speed and temperature	Only consider high wind speed and reference temperature of 15 °C
Altitude	0 m AMSL

4.9.3 Construction and maintenance loading

4.9.3.1 In addition to the loading conditions indicated in SANS 10280-1, strain towers which are to be back-stayed during stringing operations shall be designed to withstand loads applied to the tower during back-stayed stringing operations.

4.9.4 Security loads

4.9.4.1 Failure containment conditions: Towers shall be designed for the following failure containment conditions at 15°C and no wind:

Tower Type	**Number of conductors broken**	**Conductor tension at broken attachment point**
Suspension towers	One circuit and earth conductor broken	1.0 x RSL
Angle strain or terminal towers	One circuit and earth conductor broken	1.5 x EDT

Where:

RSL = Residual static load, i.e. the reduced conductor tension due to swing of suspension insulator calculated by adding half of the insulator string length to the span length at everyday conditions.

EDT = every day tension at 15°C and no wind

Vertical loads from broken span side of structure shall be taken as weight of phase conductor of length equal to twice the conductor attachment height of the conductor.

4.9.4.2 Broken wire conditions: Tower shall be designed for the following broken wire conditions at 15°C and no wind:

Tower Type	**Number of conductors broken**	**Conductor tension at broken attachment point**

Suspension towers	Any one earth or phase conductor broken	1.5 x RSL
Angle strain or terminal towers	Any two attachments broken, phase and/or earth	1.5 x EDT

Where:

RSL = Residual static load, i.e. the reduced conductor tension due to swing of suspension insulator calculated by adding half of the insulator string length to the span length at everyday conditions.

EDT = every day tension at 15°C and no wind

4.10 Tower materials

4.10.1 General

4.10.1.1 Lattice towers, body extensions and leg extensions shall be constructed of bolted sections, flats or plates of mild steel complying with SANS 50025/ EN 10025. Compression members shall consist of sections only and not flats. Unless otherwise approved, tension members such as cross-arm ties, which are liable to be set in vibration, shall consist of rolled steel sections and not flats. Steel shall be free from blisters, scales, laminations and other defects. Steel sections shall preferably be standard sections chosen with a view to avoiding delays in obtaining material. Mill certificates shall be provided for all steel showing its origin and quality.

4.10.1.2 Bolts and nuts shall conform to DIN 7990, with some modifications as indicated.

4.10.1.3 All ferrous materials shall have chemical composition suitable for hot dip galvanizing.

4.10.2 Material grades

4.10.2.1 The following material grades shall be used:

Description	**Grade**
Steel sections	S355JR
Plates, less than 19 mm thick	S355JR
Plates, greater than 19 mm thick	S355J0

4.10.2.2 Impact properties in the longitudinal direction of all structural materials shall be determined for grade S355JR material greater than 19 mm in thickness in accordance with the Charpy V-notch test. Charpy V-notch requirements at a minimum, shall meet the requirements of 27J absorbed energy at room temperature.

4.10.2.3 Silicon and Phosphorous content of steel is limited as follows:

(1) “Aluminium Killed Steel”: Silicon (Si) = 0.01 to 0.04%, Phosphorous (P) < 0.015% maximum.

(2) “Silicon Killed Steel”: Silicon (Si) = 0.15 to 0.25% and Phosphorous (P) < 0.02% maximum.

4.10.3 Forms and shapes of hot rolled steel products

4.10.3.1 The towers shall be constructed with hot rolled steel angle sections and plates readily available of the South Africa market as described below. Steel angle sections shall be limited to those indicated in the Southern African Steel Construction Handbook published by the Southern African Institute of Steel Construction.

4.10.3.2 Steel plates shall be limited to the thicknesses: 5, 6, 8, 10, 12, 16, 20, 25, 30, 35 mm.

4.10.3.3 Any other forms or shapes required shall be readily available of the South African market and in accordance with the Southern African Steel Construction Handbook published by the Southern African Institute of Steel Construction.

4.10.3.4 Flat bars, round rods and tubes shall not be used for tower members.

4.10.4 Minimum thickness of hot rolled sections and plates

4.10.4.1 The minimum thickness of component members shall be as follows:

Sections	**Minimum Thickness(mm)**
Main leg members below bottom cross-arm	8
Main leg members above bottom cross-arm and cross-arm members	6
Other stressed members	5
Unstressed members	3
Sections using Ø16 mm bolts	3
Sections using Ø20 mm or Ø24 mm bolts	4

4.10.5 Fasteners: bolts, nuts and washers

4.10.5.1 All metal parts shall be secured by bolts, nuts and washers. Equivalent square washers may be utilized.

4.10.5.2 Bolt dimensions shall conform to DIN 7990 or equivalent, but with thread length equal to 1.5 x diameter and round flat washers having thickness of 3 or 5 mm.

4.10.5.3 The minimum bolt diameter shall be 16 mm.

4.10.5.4 Bolts shall have a maximum of two washers per bolt.

4.10.5.5 Packers shall have thicknesses of 5, 8 or 12 mm.

4.10.5.6 Earthing bolts at the earth-peak and cross arm ends shall be at least 180 mm in total length, with a 55 mm thread length, fitted with 2 nuts.

4.10.5.7 Fastener material grades shall be as follows:

Description	**Grade**
Bolts	Grade 6.8 to ISO 898 (strength after galvanizing)
Nuts	Grade 6 (strength after galvanizing)
Washers	Grade S275JR

4.10.5.8 All bolts and threaded rods shall be galvanized, including the threaded portion. Nuts shall be galvanized with the exception of the threads which shall be greased.

4.10.5.9 Fasteners positioned below the anti-climb device shall include “anti-theft” units of approved design, if specified in the **Technical (Returnable) Schedules.**

4.11 Tower design

4.11.1 Structural analysis and member resistance

4.11.1.1 A finite element structural analysis shall be carried out to determine member loads under all loading conditions specified. The resistance of tower members and connections shall be calculated in accordance with ASCE 10-97 including members carrying moment and/or tensional loads and attachment plates, unless otherwise indicated in this specification.

4.11.1.2 All combinations of leg and body extensions (assuming ground slope up to 30 degrees) shall be considered in the design of the tower.

4.11.2 Design of tower members

4.11.2.1 Tower members shall have flat surfaces uppermost where practicable. Pockets and depressions likely to hold water shall be avoided and, where unavoidable, shall be properly drained.

4.11.2.2 All diagonal-bracing members shall be connected at their point of intersection by at least one bolt.

4.11.2.3 All members shall be capable of withstanding wind induced vibration when assembled and erected as part of a structure.

4.11.3 Allowable slenderness ratios

4.11.3.1 The allowable slenderness ratio is the maximum ratio of unsupported length of compression member to their least radius of gyration (L/R)

Section	**Allowable slenderness ratio**
Main members, which shall include legs, earth-peak and cross-arm bottom chord members)	120
Stressed bracing (All other load carrying members)	200
Unstressed bracing (redundant members)	250

4.11.4 Member sizes

4.11.4.1 The maximum unsupported horizontal length of members shall not exceed the following:

(1) 1500 mm for angle section 45 x 45 x 3.

(2) All larger sections shall be governed by the slenderness ratios specified above.

4.11.4.2 To facilitate transport and galvanizing processes the maximum length of any tower member shall be 11 m.

4.11.4.3 All long members shall be of sufficient section that, after punching or drilling, they will withstand ordinary rough handling during erection.

4.11.4.4 Where members of the same size but of different thickness are to be used in the same tower, the difference in thickness shall be more than 1 mm.

4.11.4.5 Redundant bracing systems shall be arranged so that the secondary forces in any redundant member will be carried to the intersection of a non-redundant member with the leg or any other main member of the tower. When only one redundant member braces a leg or main member at a point, it shall be designed for an axial compressive load of 2.5% of the maximum load in the leg or main member it braces. When two redundant members, in planes normal to each other, are connected to a leg or main member at the same point, they shall be designed for an axial compressive load of 1.5% of the maximum load in the leg or main member they brace.

4.11.4.6 All tower members which are inclined not more than 30 degrees to the horizontal (i.e. members which could be climbed during construction or maintenance operations) shall be designed to withstand a load of 1.5 kN acting vertically at the centre of the member.

4.11.5 Maximum allowable design stresses

4.11.5.1 The maximum allowable design stresses for angle shapes shall be as follows:

(1) 350 MPa for steel ≤ 16 mm.

(2) 345 MPa for steel > 16 mm but ≤ 25 mm.

4.11.5.2 The maximum allowable design stresses for bolts shall be as follows:

(1) Shear on unthreaded portion of bolt ≤ 250 MPa.

On multiple bolt connections allowance must be made, in accordance with either SABS 0162, ASCE Manual No. 52 or ECCS No. 39, for the group effect, which will tend to decrease the permissible shear on the bolts.

(2) Tension on net area of bolt — 400 MPa.

4.11.6 Mass of tower and foundation steelwork

4.11.6.1 The calculations of mass for angles and other rolled shapes shall be in accordance with the mass per metre listed in the latest edition of the "South African Steel Construction Handbook" published by the South African Institute of Steel Construction.

4.11.6.2 All plate material shall be based on a mass density of 7850 kg/m³.

4.11.6.3 Lengths used to determine mass of members shall be based on the detailed lengths shown on the final, accepted shop drawings and not on the "ordered overall lengths". Material lost from clips, back-cuts, blocks, holes etc., shall not be deducted from the mass of a member or plate. Of the above-calculated mass, 3.5% of the uncoated material shall be used for the mass of the zinc coating (galvanizing).

4.11.6.4 The estimated tower mass is to include leg extensions, stubs, bolts, nuts, washers, shackles, anti-climbing device steelwork and galvanizing.

4.11.7 Connections

4.11.7.1 Connections shall be detailed in a manner to avoid eccentricity as much as possible. Assembly bolts shall be located as near the centre of gravity of angles as is practicable. All connections shall be bolted. Welded connections shall not be permitted.

4.11.7.2 Splices in main legs of towers shall be located immediately above bracing members.

4.11.7.3 Splices shall be provided in all foundations to facilitate the use of stub extensions and to ensure a practical splicing position for repairing main leg failures. The centre of this splice shall be approximately 500 mm above ground level.

4.11.7.4 Bolt heads rather than nuts shall be positioned on the outer faces of tower members.

4.11.7.5 A minimum of two bolts shall be provided for the connection of any member, including redundancy, having a flange width equal to, or greater than 90 mm.

4.11.7.6 The top tension members of all cross-arms, and earth conductor peaks on double circuit towers, shall be connected by a minimum of two bolts irrespective of design requirements.

4.11.7.7 Bolts of different diameters can be used on the same tower, provided that bolt sizes are not mixed in any one connection or plate.

4.11.7.8 When fastened in position, all bolts and threaded rods shall project through the corresponding nuts, with a minimum projection of 3 mm and a maximum projection of 10 mm. No threads shall be positioned in shear. To ensure this a single washer of suitable thickness shall be placed under the nut.

4.11.7.9 Spacers shall be provided, as necessary, for all gaps to prevent distortion of structural members.

4.11.7.10 Spacers between tower members, where more than one bolt is involved, shall be one plate of the required thickness. Where a single bolt is involved, the spacer may be made of up to three pieces.

4.11.7.11 Bolts and nuts that bear on sloping faces shall be provided with bevelled washers.

4.11.7.12 Assembly bolts shall not connect more than three (3) thicknesses of material.

4.11.7.13 Where members are subject to vibration, the associated bolts and nuts shall be locked by approved means.

4.11.8 Interfaces with other line components

4.11.8.1 Conductor attachment plates shall have suitable holes to attach the phase conductor or earthwire assembly.

4.11.8.2 The foundation stubs shall be cast into reinforced concrete foundations and shall accommodate all leg extensions for each type of tower.

4.11.9 Earthing of towers

4.11.9.1 Tower footing resistance for power lines are to be:

(1) 132 kV power line: ≤ 10 ohms.

(2) 275 kV power line: ≤ 20 ohms.

4.11.9.2 All legs of towers shall be earthed.

4.11.9.3 For pad and pier foundations

Prior to backfilling of foundations, a 40 mm x 3 mm galvanized mild steel strap to SABS 1431 shall be installed at each tower leg which shall run down the outermost corner of the foundation to the bottom of the excavation, laid against the full length of the peripheral wall at the lowest level of the excavation and then brought up the same corner of the leg to the end of the starting point. These two ends shall be bolted to the tower leg by a 16 mm bolt and nut. In the case of foundation with large pads, such as for type 4 soils, the earth strap is to be laid on top of the pad to provide a similar length of earth strap as would be used in the pad and chimney foundation in normal soils. The lower portion of the earth strap shall be completely covered with soft soil free from rock and stones before

excavation is backfilled. It is permissible to join the earth strap by bolting it together in the middle with 2 of 16 mm bolt using washers under the nut and the bolt-head, and sealing.

4.11.9.4 For drilled pile foundations

A 100 mm diameter hole, 5 m deep, shall be drilled adjacent to the foundations. A length of 40 mm x 3 mm galvanized mild steel strap to SABS 1431 shall be inserted to the bottom of the hole which shall then immediately and completely be backfilled with an approved conductive cement mixture. The mixture shall be adequately agitated to expel all air pockets. The strap shall be bolted to the tower leg by a 16 mm bolt and nut.

4.11.9.5 In rocky areas and areas with high resistivity, a conductive mixture, subject to approval by the Employer's Engineer, shall be used.

4.11.9.6 The price for this earthing shall be included in the price of the foundations, unless it is stated in the **Scope of Work** that provision is made or there are separate unit rates in the **Price Schedules**.

4.11.9.7 In cases where there is paint at the earth strap connection point, the paint will be neatly removed so as not to damage the galvanizing on the tower leg, prior to making the connection.

4.11.9.8 The Contractor shall measure the electrical resistance to earth of each tower by an approved method prior to the erection of the earth conductor.

4.11.9.9 In all cases where tower footing resistance exceeds 10 ohms for 132kV lines or 20 ohms for 275kV lines, a counterpoise earthing system shall be provided. The counterpoise shall comprise 40 mm x 3 mm galvanized mild steel strap to SABS 1431, buried in a trench 1 m deep, being along a route away from the tower as instructed by the Employer's Engineer.

4.11.9.10 Earth straps or counterpoise shall be painted with an approved surface tolerant primer and two coats of approved epoxy coaltar/ mastic paint, or other approved coating, for the full section above ground and down to 1 m below the finished ground level. In corrosive areas, particularly very close to the coast and in damp areas, Denso primer and tape (or equivalent) with at least 50% overlap shall be used instead of mastic paint. At the point of attachment to the tower leg, a length of 50 mm on the earth strap shall be left unpainted. All joints shall be sealed with Denso primer and tape, or equivalent. After connection to the tower, the earth strap or counterpoise shall be painted to provide a seal.

4.12 Construction and maintenance facilities

4.12.1 Attachment and service holes

4.12.1.1 All earth conductor attachment plates shall be provided with at least one additional maintenance hole of the same diameter as the attachment hole.

4.12.1.2 All phase conductor attachment plates shall be provided with at least two additional maintenance holes of the same diameter as the attachment hole, symmetrically spaced from the attachment hole.

4.12.1.3 Sufficient numbers of additional holes shall be provided, especially on the cross-arm sections of all towers for construction and maintenance work.

4.12.1.4 Additional holes shall be provided on landing plates of strain towers to cater for the attachment of tee-off landing spans in the transverse directions.

4.12.2 Step bolts

4.12.2.1 Step bolts shall be at least 180 mm in total length, with a 55 mm thread length, fitted with 2 nuts. Alternative types of step-bolts may be specified in the Scope of Work.

4.12.2.2 For double circuit towers, two diagonally opposite legs shall be equipped with step bolts.

4.12.2.3 For single circuit towers, one leg of each tower shall be equipped with step bolts.

4.12.2.4 Step bolts shall start immediately above the anti-climb device and extend to the earth conductor cross-arm.

4.12.2.5 The bolts shall be uniformly spaced by not more than 400 mm and shall be continuous and in-line over gusset plates.

4.12.2.6 Below the anti-climb, holes only shall be provided for step bolts.

4.12.2.7 The step bolts shall be fixed to the main leg members of the tower by means of two hexagonal nuts. The length of the cylindrical section of each step bolt shall not be less than 150 mm, as measured from the outside face of the main leg to the bolt head.

4.12.2.8 Holes for step bolts shall be on all leg extensions from ground level up. No step bolts shall be installed below the anti-climb device except temporarily for construction purposes.

4.13 Tower accessories

4.13.1 Anti-climb devices

4.13.1.1 Anti-climb devices shall be designed for each tower and shall have access gates fitted with suitable locks, subject to approval by the Employer's Engineer.

4.13.1.2 The anti-climb devices are to be attached at a height of not less than 3 m and not more than 4.5 m above natural ground level.

4.13.1.3 Where long leg extensions are used, an anti-climb device shall be installed on individual legs at a height as indicated above.

4.13.1.4 Anti-climbing devices shall be formed by stringing onto projecting steel supporting brackets, barbed-wire consisting of 2.5 mm diameter double-strand uni-directional twist pattern, fully hot-dip galvanised mild steel line wire with 2.5 mm diameter 4-point barbs spacing 150 mm, fully hot-dip galvanised.

4.13.1.5 Spacing between the parallel wire strand shall not be more than 100 mm, the first being not more than 100 mm from the tower face, and forming an overhang of not less than 500 mm beyond the outer face of the tower. This overhang distance shall be maintained at the tower corners. The strands of barbed-wire shall be secured at intervals not exceeding 2 m, by spacers formed by pieces of the same barbed-wire bound to the strung barbed-wire by galvanized binding wire.

4.13.1.6 Where barbed-wire other than galvanized steel is specified, the spacers and binding wire shall be compatible.

4.13.1.7 The brackets of the tower legs supporting the anti-climb device shall be designed to carry the weight of a linesman.

4.13.1.8 Where the design of the towers is such that they can be climbed on the inner face, a similar anti-climbing device shall extend from the inner face of the tower.

4.13.1.9 The price/s for the brackets, barbed-wire, associated items and installation thereof shall be included in the price of the tower, unless separate provision is made for unit rates in the **Price Schedules**.

4.13.2 Tower labels

4.13.2.1 All towers shall be fitted with one set of circuit (line) designation labels, circuit number discs and phase indication discs/ plates. These shall be manufactured from 2 mm to 3 mm mill-finished anodized aluminium plates, powder coated. The cost of these shall be included in the price of the towers, unless provision is made for unit rates in the **Price Schedules**.

4.13.2.2 Circuit (line) designation labels shall be 400 mm wide and 230 mm high. These shall have a yellow background with black letters of 50 mm height. The label text shall contain the circuit (line) name and

tower number. There shall be a black border between the text and edge of the label. The label layout shall be to the approval of the Employer's Engineer. Labels shall have two 17.5 mm diameter holes for mounting.

4.13.2.3 Circuit number labels shall consist of a white 125 mm diameter disc with the circuit number (1 or 2) of height 60 mm in black. Double circuit towers shall have four circuit number discs and single circuit towers shall have two. Circuit number discs shall have one 17.5 mm diameter hole for mounting.

4.13.2.4 Phase indication discs shall consist of a red, yellow and blue 125 mm diameter disc, with white R, Y, B text (60 mm height) on each respectively. Double circuit towers shall have two sets of discs and single circuit towers one set. Phase indication discs shall have one 17.5 mm diameter hole each for mounting.

4.13.2.5 The circuit (line) designation label shall be mounted on a hot dipped galvanized mild steel bracket (main horizontal bracket) constructed of flat bar with a layout to the approval of the Employer's Engineer. One phase disc set and circuit number disc shall first be mounted on a bracket (vertical layout), and then this bracket will be mounted vertically onto the main horizontal bracket on one side of the designation label. A second vertical bracket with the other phase disc set and circuit number will be mounted similarly but on the other side of the designation label. The labels and discs shall be attached to the brackets by means of hot dipped galvanized steel bolts with fibre washers to avoid damage to the powder coat finish. The main horizontal bracket (with the label and vertical bracket attached to it) shall be attached to the tower above the anti-climb device but within 5 m of ground level by means of galvanized steel J-bolts. The second set of circuit number labels shall be installed on the first step bolts on the tower on the relevant circuit sides. No drilling through tower members for the attachment of labels will be permitted.

4.13.3 Animal guards

4.13.3.1 Animal guards shall be provided to the lower portion of towers to reduce the risk of livestock being caught in the angles between tower members.

4.13.3.2 A flat member, 50 mm wide, shall be provided above the intersection of the main leg and the diagonal, such that the open distance along the upper edge of this member is not less than 120 mm and not more than 140 mm.

4.14 Fabrication

4.14.1 General

4.14.1.1 All tower parts shall be fabricated in accordance with the dimensions, arrangements, sizes, weights, thicknesses and material quantities indicated on the workshop detail drawings and generally carried out in accordance with ACSE 10-97 and SABS 1200H unless indicated otherwise herein. Workmanship and finish shall be equal to the best modern practice for transmission tower work.

4.14.1.2 Fabrication shall be to exact dimensions to ensure correct alignment during erection. All members shall be cut to jig and all holes shall be punched or drilled to jig.

4.14.1.3 Prototypes, if required as per the Scope of Work, of tower types with the various combinations of body and leg extensions shall be assembled at the factory premises to confirm the dimensions and fitment of all members. Prototype inspection certificates shall be prepared for all tower types. Arrangements, with adequate notice period, shall be made for the prototypes to be inspected by the Employer's Engineer. If prototypes are a requirement in the initial Scope of Work or as a variation in the contract, payment shall be made at the specific unit rates quoted in the **Price Schedules**, or alternatively as a reimbursable expense where rates do not exist, or a combination of both.

4.14.1.4 Tower parts shall be neatly finished and free from kinks or twists. Holes, blocks and clips shall be made with sharp tools and shall be clean-cut without torn or ragged edges.

4.14.1.5 Shearing and cutting shall be neatly and accurately done. Cuts shall be clean without drawn or ragged edges. Particular care shall be taken in the edge finish of plates subjected to large bending moments or large bends in fabrication. The minimum radius of sheared edges shall be 2 mm.

4.14.1.6 Redundant material on gusset plates shall be removed.

4.14.1.7 All holes in structural steel less than 18 mm thick may be punched to full size unless otherwise noted on the accepted drawings. Holes shown on the drawings as drilled holes, and all holes in structural steel 18 mm or more in thickness, shall be drilled or sub-punched and reamed. Finished holes shall be clean and free of burrs.

4.14.1.8 For punching holes to full size, the diameter of the punch shall not be more than 2 mm larger than the nominal diameter of the bolt, and the diameter of the die shall not be more than 2 mm larger than the diameter of the punch.

4.14.1.9 For sub-punching, the diameter of the punch shall be 6 mm smaller than the nominal diameter of the bolt, and the diameter of the die shall not be more than 3 mm larger than the diameter of the punch. Sub-punching for reamed work shall be such that after reaming, no punched surface shall appear in the periphery of the hole.

4.14.1.10 Where holes are reamed or drilled, the diameter of the finished hole shall not be greater than the nominal diameter of the bolt, plus 2 mm.

4.14.1.11 Elongating of holes on site will not be permitted. Defective holes may not be refilled by welding.

4.14.1.12 Bending of tower parts shall be according to accepted international practice. All steel of grade S355JR/0 shall be hot-bent.

4.14.2 Marking

4.14.2.1 All tower members and parts shall be hard stamped, with numerals and letters of minimum 20 mm height and minimum 1 mm depth, before galvanizing, with the following marking:

(1) Manufacturer's identification marking consisting of a maximum of 3 characters.

(2) Tower Designation, e.g. 2D30.

(3) Manufacturer's tower code, e.g. 247B, 2212, 1322B, 213B.

(4) Member identification number.

As indicated on the workshop and erection drawings.

4.14.2.2 The Manufacturer's identification, tower code and member identification number shall be consistently stamped in the same relative location near the ends on all pieces, and shall be positioned so that the marking is visible after the tower is assembled. No other marking shall be used. The Manufacturer's identification marking shall consist of a minimum of two letters and shall be of the same height as the tower code and member identification number. Acceptance of the marking shall be obtained prior to usage. Pieces having the same mark shall be interchangeable.

4.14.2.3 In addition, all members up to the anti-climbing device level shall be stamped with the words "**TE-HV Lines**" at 300 mm to 500 mm intervals.

This stamp shall be done before galvanising for members fabricated in the tower fabrication workshop. For maintenance related steel replacement work, where steel is cut to size on site, the words "TE-HV Lines" shall be stamped on site using a portable compression tool, either hydraulic or electrically operated. The stamped area shall be adequately cleaned and an approved zinc rich primer shall be applied.

4.14.2.4 Marking of members of grade S355JR/0 material shall be followed with a letter "H" to indicate high strength steel.

4.14.2.5 The marking shall be consistently in the same relative location near the ends on all pieces. No other marking shall be used.

4.14.2.6 Acceptance of the marking shall be obtained prior to usage.

4.14.3 Traceability

4.14.3.1 Traceability between fabricated components and mill test certificates for mechanical characteristics and chemical composition shall be maintained at all times.

4.14.4 Galvanizing

4.14.4.1 Unless specifically mentioned to the contrary, iron and steel shall be galvanized in the factory after fabrication, i.e. after cutting, sawing, drilling, punching, filing, bending and machining. The zinc coating shall be uniform, clean, smooth and as free from spangle as possible. Galvanizing shall be applied by the hot dip process. The Contractor shall avoid the use of steel that results in poor quality or defective galvanizing.

4.14.4.2 Heavy duty galvanizing is required on all parts that are to be hot dip galvanized. Written proof of such shall be provided by the Contractor. Unless otherwise specified in the **Technical (Returnable) Schedules**, the minimum quantities of zinc coating shall be 350 g/m^2 for bolts, nuts and washers and 600 g/m^2 for all other parts. Should this not be attainable, the Bidder shall indicate so in his bid and provide alternatives.

4.14.4.3 Excessive thickness of zinc shall not be accepted because, although it may provide more protection, it is more prone to brittleness and can be damaged during transport or handling.

4.14.4.4 The Galvanizer/s shall be registered with the Hot Dipped Galvanizing Association of South Africa, and ISO 9001 and 9002 certified.

4.14.4.5 The preparation for galvanizing and the galvanizing itself shall not distort or adversely affect the mechanical properties of the materials.

4.14.4.6 Where there is a possibility of white rust forming during transportation, special treatment during the galvanizing process shall be undertaken. The Contractor shall inform the Employer's Engineer and provide relevant technical details.

4.14.4.7 Quality control during the galvanizing process shall be based on sampling per item sizes or combined size groups, rather than a sample on a complete batch of items of different sizes. Since the thickness of the steel is a factor in the zinc coating thickness, the sampling process shall take into consideration the material thickness as well. Alternatively, sampling could be based on batches with similar zinc coating thicknesses.

4.14.4.8 All tower members shall be suitably straightened after galvanizing without causing damage to the galvanizing surface or to the member itself. No curved, bent or twisted members will be accepted. All possible care shall be taken to avoid damaging the zinc coating in transit or during tower assembly or erection.

4.14.5 Duplex coating

4.14.5.1 Where duplex coating is required in addition to galvanizing, this shall be specified in the **Technical (Returnable) Schedules.**

4.15 Tower tests

4.15.1 Type tests

4.15.1.1 All tower tests shall have previously been conducted on the tower series offered. Test certificates shall be included with the bid. If no test certificates are provided, the cost of tower type tests will be included in the comparative process for bid adjudication.

4.15.1.2 If testing is required by the Employer's Engineer, one tower of each standard type shall be assembled at an approved test station and shall be erected on a rigid test foundation. The tower shall be subjected to such tests, approved by the Employer's Engineer, as will demonstrate that the tower has a factor of safety not less than that specified in this specification, without showing any signs of failure or permanent distortion

4.15.1.3 If required by the Employer's Engineer, the tower shall then be tested to destruction, and the failing load recorded.

4.15.1.4 Tower components shall be galvanized prior to test. No tower or part thereof submitted to these tests shall be used on the contract works.

4.15.2 Sample tests

4.15.2.1 Samples of material shall be tested in accordance with SANS 50025/ EN 10025 AND SANS 1431.

4.15.2.2 Samples of material for fittings shall be tested in accordance with IEC 61394.

4.15.2.3 Bolts and nuts shall be tested in accordance with DIN 7990/ SANS1700.

4.15.2.4 Samples of galvanized material shall, unless otherwise approved, be subjected to the following tests:

(1) Materials other than wires: SANS 121/ ISO 1461, amended in respect of thickness of coating.

(2) Wires, including barbed type: SABS 675

5.0 Conductors and Conductor Hardware and Accessories

5.1 General

5.1.1 The specification is applicable to the following range of conductors: all aluminium alloy conductors (AAAC), aluminium conductor steel reinforced (ACSR), galvanized steel wires, and their respective joint materials and jointing installation tools. OPGW may consist of an aluminium alloy buffer or a stainless-steel buffer with an aluminium alloy coating.

5.2 Normative references

Document No.	Document Title
IEC 60050-466	International Electrotechnical vocabulary - Chapter 466: Overhead lines.
SANS 61089 (IEC 61089) and Amendment 1	Round wire concentric lay overhead electrical stranded conductors.
IEC 60104	Aluminium-magnesium-silicon alloy wire for overhead line conductors
SANS 182-2	Conductors for overhead electrical transmission lines- Part 2: Stranded aluminium conductors.
SANS 182-3	Conductors for overhead electrical transmission lines- Part 3: Aluminium Conductors, steel reinforced.
BS 215-1	Specification for Aluminium conductors and aluminium conductors, steel-reinforced - For overhead power transmission - Part 1: Aluminium stranded conductors
IEC 60888 (and SANS 182-5)	Conductors for overhead electrical transmission lines- Part 5: Zinc-coated steel wires for conductors and stays.
IEC 60889	Hard drawn aluminium wire for overhead lines.
IEC 61394	Overhead lines - Requirements for greases for aluminium, aluminium alloy and steel bare conductors.
IEC 61395	Overhead electrical conductors- creep test procedures for stranded conductors
IEC 61897	Requirements and tests for Stockbridge type Aeolian vibration damper.
SANS 61284 (IEC 61284)	Overhead lines - Requirements and tests for fittings
IEC 61854	Overhead Lines - Requirements and Tests for Spacers
SANS 1700	Fasteners: General requirements and mechanical properties
SANS 121	Hot-Dip galvanized coatings on fabricated iron and steel articles-Specification and test methods.
SANS 675	Zinc-coated fencing wire

OHS Act, 85 of 1993, as amended	Occupational Health and Safety Act 85 of 1993, as amended, incorporating the 2014 Construction Regulations. Published by South African Government Press, under auspices of the Department of Labour
SABS 10280-1	Overhead power lines for conditions prevailing in South Africa.
ISO 9001	Quality System Model for Quality Assurance in Design/ development, Manufacture and Testing
ISO 9002	Quality System Model for Quality Assurance in Production, Installation and Servicing
South African Civil Aviation Authority	Objects Affecting Airspace http://www.caa.co.za/

5.3 Design and manufacturing requirements

5.3.1 The conductor shall be designed and manufactured in accordance with the respective standards:

(1) All aluminium alloy conductor as per IEC 60104 and fabricated to meet IEC 61089 requirements, and sizes as per BS 215.

(2) Aluminium conductor steel reinforced as per IEC 60889 and 60888 and SABS 182-3, and fabricated to meet IEC 61089 requirements.

(3) Galvanized steel wires as per IEC 60888 (and SABS 182-5) and fabricated to meet IEC 61089 requirements.

(4) OPGW and Underground optic fibre cable specifications are detailed in the OPGW Specifications.

5.3.2 The sizes and associated characteristics are specified in the **Technical (Returnable) Schedules**.

5.3.3 The conductor shall be concentrically stranded, with successive layers in opposite lay, but such that the outer layer shall be in the right-hand spiral. The wires in each layer shall be evenly and closely stranded around the underlying wire or wires.

5.3.4 The maximum working tension of a phase conductor shall not exceed 33.33% of its ultimate tensile strength, (i.e. a factor of safety of 3). The maximum working tension of an earth conductor shall not exceed 40% of its ultimate tensile strength, (i.e. a factor of safety of 2.5). The minimum requirements of the OHS Act shall also be complied with.

5.3.5 The maximum final tension of a conductor in still air at 15°C shall not exceed 20% of its UTS. For OPGW, the Manufacturer's recommendation shall be used, however this shall not exceed the 20% value.

5.3.6 The minimum temperature of conductors shall be taken as -5°C. The maximum temperature of conductors shall be as per the stipulated design templating temperatures.

5.3.7 For landing spans/ down leads, the maximum working tension of the conductors shall not exceed 4.5kN per conductor at -5°C.

5.3.8 The phase conductor may be used in single or twin configuration. In the case of twin conductors, the conductors shall be disposed horizontally and the separation shall be 380 mm along the span, and reduced to 230 mm with 2 spacers along the jumper section. The earth wires are used as single conductors attached at the tower earth-peaks.

5.3.9 For permissible joints during manufacture, the provisions of SANS 61089 (IEC 61089) shall be adhered to.

5.3.10 As protection against corrosion, all the conductors shall be greased except the outer surface of the wires in the outer layer, Case 4 of SANS 61089 (IEC 61089). The grease shall be of the high melting point type in accordance with IEC 61394.

5.3.11 The Contractor shall supply Stress-Strain and Creep data for the specified conductor/s in the **Technical (Returnable) Schedules**. The data shall be in the form of coefficients and, additionally, in the form of stress-strain curves. Conductor's Stress-Strain and Creep data shall be obtained from stress-strain tests on the conductor/s produced under this Contract, if so required in the **Technical (Returnable) Schedules**.

5.4 Joints and repair sleeves

5.4.1 If joint materials are required, the Contractor shall supply such materials suitable for the specified conductors, and pertinent instructions.

5.4.2 Tension joints for phase and standard earth conductors shall be of the compression type. At mid-spans, for ACSR conductors the joint sleeve shall consist of a carbon steel compression sleeve for the core and an aluminium alloy compression sleeve for the overall conductor. For AAAC conductors, the joint sleeve shall be aluminium alloy. The filler compound shall be per the Manufacturer's recommendation.

5.4.3 Repair sleeves shall be made of aluminium alloy. Repair sleeves may be of the preformed type.

5.4.4 The complete conductor tension joint or conductor with a repair sleeve, when installed according to the Contractor's instructions, shall have a minimum mechanical strength equal to 95% of the rated tensile strength (RTS) of the conductor.

5.4.5 The tensile strength of the finished joint within a jumper must be no less than 50% of the ultimate breaking strength of the conductor.

5.4.6 The electrical resistance of the installed joints shall be no more than that of an equal length of bare conductor. During stringing activities, the Contractor shall make available a calibrated micro-ohm-meter to check the resistance of the joint.

5.4.7 The Contractor shall provide drawings for the joint sleeves, including the lengths before and after compression.

5.5 Vibration dampers

5.5.1 All line and earth conductors shall be fitted with multi-frequency Stockbridge pattern vibration dampers. The number of vibration dampers required per span is specified in the **Technical (Returnable) Schedules**. Spiral dampers shall be used for OPGW conductor, unless otherwise recommended by the Manufacturer of the OPGW, and subject to acceptance by the employer's Engineer. For any type other than the spiral for the OPGW, armour rods shall be fitted to protect the OPGW from damage.

5.5.2 For Stockbridge pattern dampers mounted using bolts, the bolts shall be locked in an approved manner. Stockbridge pattern dampers shall be mounted using preformed wires where recommended or required by the conductor Manufacturer, or for any special application where the conductor is aluminium and not an alloy.

5.5.3 The damper shall be designed for a working life of at least 40 years and the design shall take full account of environmental factors, including conductor temperature variations between -10°C and 80°C, ultraviolet radiation, ozone and atmospheric pollutants.

5.5.4 The material and surface treatments shall be selected to ensure that the dampers will resist atmospheric corrosion for a minimum of 40 years.

5.5.5 The damper shall be designed so as to damp Aeolian vibration. The damping efficiency shall be a minimum of 70%.

5.5.6 The conductor groove in the damper clamp for each damper size shall fit the conductor diameter closely and shall be free of burrs and rough edges.

5.5.7 The dampers shall be able to withstand the mechanical stresses that can arise during transport handling and installation in temperatures as low as –10°C.

5.5.8 The damper clamp shall have sufficient grip to maintain the damper's position on the conductor without damaging the conductor or causing premature fatigue damage on the conductor.

5.5.9 The dampers for phase conductors shall be free from visible corona at the test voltage. This means that corona should not be seen by either a camera or naked eye (in a dark room) during test.

5.5.10 The fitted damper assembly shall be electrically continuous with the conductor in order to avoid short-wave radio interference.

5.6 Spacers

5.6.1 On lines employing more than one conductor per phase, spacers shall be installed to separate the individual conductors of each phase.

5.6.2 The spacer must be stiff enough to maintain the bundle geometry without permanent deformation of the spacer under fault conditions for the system fault levels specified in the **Technical (Returnable) Schedules**, alternatively other capacities if specified in the **Technical (Returnable) Schedule**, while being flexible enough to allow vibrations and oscillations to pass through.

5.6.3 The span spacers shall be of the flexible type without hinge pins or other moving metal parts and shall allow a limited longitudinal, vertical and torsional movement of the clamps. The spacer design must ensure that the spacer will restore the bundle's nominal configuration when the external loads are removed. The geometry of spacers should be optimized to avoid any undue rubbing where the rods make contact the conductor.

5.6.4 Spacers shall be located less than 65 m apart. The first spacer in each span shall be fitted 10 m from the tower centre line.

5.6.5 All twin jumper conductors shall be fitted with at least 2 rigid aluminium spacers with conductor centre of 230 mm. These spacers may incorporate weights to limit jumper swing. The clamp mouth shall be provided with an adequate radius to prevent damage to the conductor.

5.6.6 All bolts, nuts and washers on spacers shall be manufactured from stainless steel and locked in an approved manner.

5.6.7 Spacers shall be profiled to minimise the possibility of Corona and Radio Interference discharge at specified line voltages and satisfy the line corona tests.

5.6.8 Spacers shall comply with and be tested in accordance with IEC 61854 "Overhead Lines - Requirements and Tests for Spacers".

5.7 Flight path marker spheres

5.7.1 Power lines shall be marked when crossing a river, valley or major highway.

5.7.2 Where required marker spheres shall be of a diameter of not less than 600 mm.

5.7.3 Each marker shall be made of a complete sphere and the complete unit shall be of only one colour. There shall be 2 colour options, namely, Red (or Orange) and White.

5.7.4 The spacing between the red/orange coloured sphere and white coloured sphere shall not exceed 30m. Furthermore, the spacing between the spheres and the supporting towers shall also not exceed 30m.

5.7.5 Sphere clamps must be made of aluminium and adapt to the diameter of the conductor.

5.7.6 Spheres must be constructed from Aluminium or UV and ozone resistant Polyethylene for direct attachment to high corona, high voltage ACSS/ACCR/ACSR/OPGW lines and rated up to 250°C and 275 kV.

5.7.7 All bolts, washers shall be A4 grade stainless steel and nuts shall be of a different grade to prevent the threads from locking, unless otherwise approved by the Engineer.

5.7.8 For aluminium based conductors and OPGW shield wires the Warning Spheres shall be installed over armour rods.

5.7.9 Drain holes must be provided to prevent accumulation of water inside the spheres.

5.7.10 The spheres shall be fitted to the highest conductor.

5.7.11 Where power lines cross a river or valley, the co-ordinates (latitude and longitude in degree, minute, seconds and tenth of seconds format) and the height of the line above the valley or river, shall be communicated to the Commissioner for Civil Aviation for publication in the appropriate media.

5.8 Drums

5.8.1 The conductors shall be rolled on drums stoutly constructed of good quality treated wood (or steel for conductor to be retained by the Employer). Drums shall be securely battened around the perimeter to give maximum protection to the conductor and the earthwires and correct direction of rolling indicated with an arrow in a manner not easily removable.

5.8.2 The first layer of conductors on drums shall be secured to the hub in a manner avoiding damage to subsequent layers.

5.8.3 All wooden drums shall be protected during transportation and on site and Employer's stores should the un-used conductors be stored for future use, from deterioration by termite or fungus attack by an approved impregnation treatment at the factory before dispatch.

5.8.4 When conductors are ordered for spares and hence long-term storage, these shall be supplied in on steel drums, unless otherwise specified.

5.8.5 The steel drums shall be suitable to be mounted and rotated on a 120 mm spindle. Details of the various parts of the drums to ensure suitability shall be agreed upon with the Employer. The steel drums shall be suitably hot dip galvanized or upon approval painted with an approved anti-rust paint. The drum capacity shall be for approximately 2 km of conductor.

5.8.6 The drums shall be marked in legible and indelible letters on a metal plate, affixed to it in a non-detachable manner, giving the following particulars:

(1) Conductor Code and type.

(2) Cross-section of conductor (mm^2).

(3) Serial number of drum/ reel.

(4) Client name, such as: eThekwini Municipality, Electricity Service Unit.

(5) Client address and contract number.

(6) Client stock number in 10 cm high bold text/numerals (if issued).

(7) Manufacturer's name and country of origin.

(8) Length (m) and mass of conductor (kg) on drum/ reel.

(9) Stranding.

(10) Gross mass/weight (kg).

(11) Size of drum/reel.

(12) Year of manufacture.

(13) Direction of rolling of drum/ reel.

All markings shall appear on both sides of the reel.

5.9 Conductor tests

5.9.1 The conductor shall be subjected to tests as per IEC 61089.

5.9.2 More specifically, mechanical and electrical resistivity routine tests shall be carried out in accordance with IEC 61089.

5.9.3 Tests on OPGW and Underground Optic Fibre Cable shall be carried out in accordance with the relevant Specifications.

5.9.4 Specific requirements for testing:

(1) Tests shall be carried out on wire samples and on finished conductor in accordance with the latest relevant standard and as specified herein.

(2) Tests shall be carried out in the presence and under the control of the Employer's Representative/s, except in specified or approved cases where test certificates are accepted. The Contractor shall obtain confirmation from the Employer prior to testing.

(3) All test results shall be reviewed and approved in writing by the Employer's Representative.

(4) All tests shall be carried out by and at the expense of the Contractor/ Manufacturer who shall supply all the pieces and specimens as well as all apparatus, instruments and equipment.

(5) Not less than 4 weeks-notice of all tests shall be given.

(6) The Contractor shall not be entitled to any extension of the time of completion due to the failure of any test or the rejection of any part of the materials as a result of any test.

(7) The full range of type and sample tests specified in the relevant standard and this specification shall be carried out as applicable.

(8) Sample tests shall be carried out in the Manufacturer's factory or at any other mutually approved place. Tests on wire samples may be carried out before or after stranding. In the case of finished conductors, tests may be replaced by calculations based on the test results on the individual wires. The Contractor must furnish these calculations. Tests shall be carried out on a minimum of 10% of the drums offered for inspection and, in such cases, each wire shall be tested. Drums to be sampled shall be selected at random and samples taken from the outer end of the drums. The length of the sample of the conductor taken shall be sufficient to allow all tests to be performed on the same specimen of wire. In order to check the grease, a sample of the conductor shall be taken from one drum of each inspection lot.

(9) Type test report/certificate from an independent testing laboratory shall be submitted to the Employer.

5.9.5 Test results upon delivery:

The following sample tests results shall be submitted to the Employer upon delivery of the conductors:

(1) For aluminium wires: Diameter measurement, Tensile strength test, Elongation test, Resistivity test, Wrapping test.

(2) For complete conductor: Surface condition, Diameter, Inertness, Lay ratio and direction, of lay, Number and type of wires, Mass per unit length, Mass of grease per unit length, Drop point of grease.

5.9.6 Acceptance / Rejection:

(1) Failure of a test specimen to comply with any one of the relevant standards and the requirements of this specification shall constitute grounds for rejection of the lot represented by the specimen.

(2) If any lot is so rejected, the Contractor/ Manufacturer shall have the right to retest, only once, all individual drums of conductor in the lot and submit those, which meet the requirements, for acceptance. The Employer reserves the right to select the sample for such testing.

6.0 Insulators

6.1 General

6.1.1 This specification covers the technical and associated requirements for composite insulators and fittings. The composite insulators shall be of the long rod type for use on phase and earth conductors and OPGW, in AC overhead transmission power lines rated 132 kV and 275 kV.

6.2 Normative references

Document No.	Document Title
IEC 60120/ SANS 60120	Dimensions of ball and socket couplings of string insulator units
IEC 60372/ SANS 60372	Locking devices for ball and socket couplings of string insulator units-dimensions and test.
IEC 60383-1/ SANS 60383-1	Insulators for overhead lines with a nominal voltage above 1000 V Part 1 Ceramic or glass insulator units for ac systems: Definitions, test methods and acceptance criteria
IEC 60383-2/ SANS 60383-2	Insulators for overhead lines with a nominal voltage above 1000 V Part 2 Insulator strings and insulator sets for ac systems – Definitions, test methods and acceptance criteria
IEC 60437	Radio interference test on high voltage insulators
IEC 60471/ SANS 60471	Dimensions of clevis and tongue couplings of string insulator units.
IEC 60507	Artificial pollution tests on high voltage insulators to be used on ac systems.
IEC 60587	Track resistance of the material.
IEC 60815/ SANS 60815	Guide for the selection of insulators in respect of pollution conditions.
IEC 61109/ SANS 61109	Composite insulators for ac overhead lines with a nominal voltage greater than 1000V- Definitions, test methods and acceptance criteria.
IEC 61211/ SANS 61211	Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000 V - Impulse puncture testing in air
IEC 61284/ SANS 61284	Overhead lines- Requirements and tests for fittings
IEC 61466-1/ SANS 61466-1	Composite string insulator units for overhead lines with a nominal voltage greater than 1 000 V – Part 1: Standard strength classes and end fittings
IEC 61467/ SANS 61467	Insulators for overhead lines with a nominal voltage above 1 000 V – AC power arc tests. (This test is excluded in IEC 61109)
IEC 61952	Composite line post insulators for ac overhead lines with a nominal voltage greater than 1000V – Definitions, test methods and acceptance criteria.

IEC 62217	Polymeric insulators for indoor and outdoor use with a nominal voltage >1 000 V – General definitions, test methods and acceptance criteria
SANS 121/ ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles-specifications and test methods.
OHS Act, 85 of 1993, as amended	Occupational Health and Safety Act 85 of 1993, as amended, incorporating the 2014 Construction Regulations. Published by South African Government Press, under auspices of the Department of Labour

6.3 General requirements

6.3.1 The insulators shall comply fully with the requirements of IEC 61109, except where specified below.

6.3.2 The Manufacturer shall be an ISO 9001 certified company.

6.3.3 The insulators shall be of the long rod type suitable for both horizontal and vertical mounting, i.e. as a strain and a suspension insulator.

6.3.4 The insulator shall have an impenetrable design to prevent humidity and moisture ingress.

6.3.5 Insulation materials shall be at least 3 mm thick. The insulator design shall ensure that the core is totally sealed.

6.3.6 The insulator housing shall be manufactured from silicon rubber only. The moulding process for the sheath, shed and end fitting seal shall be high pressure high temperature injection moulding in one step. The one step injection moulding shall cater for the single sealing system with HTV to produce the overcasting/ overmoulding on the end fittings. Gravity and lower pressure moulding are not acceptable.

6.3.7 Excess insulation material that is formed during the extrusion/moulding process shall be removed to affect a neat and smooth profile to prevent the entrapment of pollutants.

6.3.8 Insulators affected by chips, pits or blisters in any part of the housing, with the exception of sheds, will be rejected. Chips, pits and blisters, if they only affect sheds, as well as scratches and shrink marks will be accepted, provided that each single defective area is less than 25mm^2 and its depth less than 1mm. Moreover, the total defective area shall not exceed 0.2% of the whole composite insulator surface.

6.3.9 The insulators shall have the minimum phase-to-ground specific creepage of 31 mm/kV unless otherwise specified in the **Technical (Returnable) Schedules**. This is to be based on the total creepage distance divided by 110% of the nominal phase-to-phase voltage.

6.3.10 Dimensions shall be stated in the **Technical (Returnable) Schedules**.

6.4 Insulator core

6.4.1 Composite insulators shall be constructed using a central member of solid high-density axially aligned glass-fibre-reinforced pultruded epoxy resin rod. Hollow cores are not acceptable.

6.4.2 The epoxy resin shall be hydrolysis resistant. The glass fibre shall be acid resistant.

6.4.3 The core shall be of uniform cross-section and free of cracks and voids.

6.4.4 The sheath over the rod shall be of high-temperature vulcanized (HTV) silicone rubber, minimum thickness of 3 mm, to ensure optimum adhesion.

6.5 Shed material and design

6.5.1 The sheds shall be HTV injected moulded from silicon rubber which is stabilised against the effects of ultraviolet and other solar radiation and the effects of airborne contaminants prevalent within the operating environment.

6.5.2 The Contractor shall provide evidence of the satisfactory performance of the shed material in these adverse environmental conditions.

6.5.3 The preferred colour for the shed material is grey RAL 7035.

6.5.4 Sheds with an open aerodynamic profile are preferred. Under-ribbed designs are not acceptable. Insulator shed profiles shall be designed in accordance with IEC 60815.

6.5.5 The insulator's shed diameter shall not be greater than 255 mm. Sheds shall be strong enough to withstand the expected handling stresses. The sheds shall maintain their shape during handling storage and in-service operation.

6.5.6 The dimensions relating to the insulator profile shall be stated in the **Technical (Returnable) Schedules**.

6.5.7 The minimum ratio of shed spacing to shed projection shall be **0.8**.

6.6 Sealing of core and end-fittings

6.6.1 The interface between the rod and sheds, and between the rod, sheds and end fittings, shall be completely sealed against the atmosphere and moisture ingress so as to absolutely prevent the occurrence of electrical discharge along the interface.

6.6.2 In order to prevent moisture ingress into the core and end-fitting, the design of the insulators shall be such as to ensure that the core is totally encapsulated and fully sealed from the environment, along the core length and particularly at and within the end fittings. The HTV silicone rubber injection overmould at the end-fitting junction shall provide the additional seal to the normal crimp seal. Application of a sealant after the injection mould process at the external interface point to provide the complete sealing requirement is not acceptable as experience has shown that moisture migrates into the fitting and this is evident by the corrosion of the inside of the fitting.

6.6.3 In order to limit the number of interface junctions, insulators shall have a housing that is directly extruded in one piece onto the core.

6.6.4 The interface seal shall be maintained under all mechanical loading conditions applied to the insulators. The interface seal must also prevent ingress of moisture under loads subjected during high-pressure water jet washing while in service.

6.6.5 The Bidder shall provide information explaining the construction of the interface between core and housing and the core, housing and end fittings with respect to the elimination of moisture ingress and subsequent longitudinal tracking.

6.7 End fittings

6.7.1 *Phase conductor insulator*: The coupling shall be ball and socket type to SANS 60120, unless otherwise specified in the **Technical (Returnable) Schedules** and/or **Drawings**. Socket coupling shall be provided on the upper end and a ball coupling on the lower end of the insulator. The socket coupling shall be provided with a retaining clip or locking device.

6.7.2 *Earthwire and OPGW insulator*: The coupling shall be clevis/clevis or clevis/tongue type to SANS 61466-1, as may be specified in the **Technical (Returnable) Schedules**. The clevis coupling shall

be provided with a bolt and washer and retaining clip or locking device, to approved design and material standards.

6.7.3 Hot-dipped galvanized components must be in compliance with SANS 121, where the minimum thickness of the zinc coating shall be that for heavy duty applications. The Bidder/Contractor shall provide the details of galvanizing. Aluminium-based end fittings are not acceptable.

6.7.4 The metal fittings at both ends of all insulators shall be made of hot-dip galvanized high-tensile strength-forged steel and be able to transfer the mechanical load to the core. The fittings must be compressed on to the core material with a coaxial or hexagonal crimping process.

6.7.5 The Bidder shall provide details concerning the method of attaching the end fittings to the core.

6.7.6 The retaining pins or locking devices for the insulators shall comply with IEC 60372.

6.7.7 All materials used (clevis, tongue, ball, socket, hump-back split pin, etc.) shall be galvanically compatible.

6.8 Electrical design

6.8.1 The impulse, flashover and withstand voltages shall not be less than the values specified in the **Technical (Returnable) Schedules**.

6.8.2 Insulators shall be free from radio interference voltages when subjected to a test voltage of 1.2 times the maximum phase to neutral voltage using the test procedure IEC 60437 and test assembly of IEC 60383-2.

6.8.3 The insulator complete with all fittings shall not exhibit visible corona formation at voltages less than 1.2 times the maximum phase to neutral voltage.

6.9 Mechanical stress

6.9.1 The strength of the insulators shall be such that the maximum working load multiplied by a factor of safety of 3 shall not exceed the failing load given in IEC 61109 and specified in the **Technical (Returnable) Schedules**.

6.9.2 Post insulator cantilever strength shall be not less than 5.3kN.

6.9.3 The minimum factor of safety requirements as per the OHS Act shall be complied with.

6.10 Coupling lengths and nominal creepage distances

6.10.1 The required coupling lengths and nominal creepage distances for the insulators are detailed in the **Technical (Returnable) Schedules**.

6.11 Corona rings

6.11.1 Corona rings are required for 132kV and 275kV insulators.

6.11.2 These shall be fitted onto the insulator end fitting on the live side of the insulator.

6.11.3 The design shall enable removal and fitting of the corona ring without having to remove the assembly when in the installed position.

6.11.4 The minimum distance between any part of the corona ring and the closest shed shall be 15 mm, so as to prevent corona discharges.

6.11.5 These corona rings shall have a rating of 50kA for 70ms.

6.12 Design changes

6.12.1 Changes in insulator materials, dimensions, manufacturing process or any other design factors to the accepted design, shall invalidate the insulator design. Any insulator so modified shall be again subjected to the design tests of this specification before delivery under this contract.

6.13 Drawings

6.13.1 Bidders' drawings shall show the outline of the insulators, together with all pertinent dimensions.

6.13.2 Drawings shall also show the details of the insulator longitudinal cross-section together with the interface between the housing and the core.

6.13.3 Each acceptance package shall include one copy of the general arrangement drawings of the insulator offered. The drawings shall clearly show the following information:

(1) Dimensions and tolerances, including end fittings.

(2) Material description, mass and fabrication details.

(3) Specified mechanical load or maximum design cantilever load.

(4) Manufacturer's/ Supplier's catalogue numbers.

(5) Location and description identification markings.

Notes:

(1) Drawings must be supplied in an electronic *.dwg, *.dxf or *.pdf format.

(2) For post insulators provide an attachment of combined loading curves.

6.14 Identification marking

6.14.1 The insulator shall be permanently marked with the:

(1) Name or the trademark of the Manufacturer.

(2) Type or model number.

(3) Year of manufacture.

(4) Specified mechanical load (SML).

(5) Batch number.

(6) Country of manufacture.

6.14.2 The markings shall be legible and durable. Markings on sheds or housing shall remain legible during the life of the insulator.

6.14.3 The batch date may be displayed on a permanently fixed pigeon ring type label to the earth end fitting if this suits the manufacturing process. The batch date shall at least show the year and month the batch was produced.

6.14.4 The markings shall be indelibly marked, moulded or engraved in or on the material of the insulator or on the end fittings.

6.15 Tests

6.15.1 All insulators shall have completed design, type, sample and routine tests described in IEC 61109, as amended, unless stipulated otherwise in this specification.

6.15.2 All insulators shall be tested in accordance with **Annexure C** of IEC 61109 for the full 5000 hours.

6.15.3 The IEC 61109 durability of end-fittings test is particularly salient because end fittings are particularly prone to water ingress due to electromechanical defects. The insulator must endure 1000 kV/microsecond steep-front voltage tests in positive and negative polarity, 25 times each without puncture of the end-fitting, housing or core material.

6.15.4 Detailed test reports shall be submitted with the Bid to confirm that the insulators offered have met or exceeded the requirements of IEC 61109 including that in **Annexure C**.

6.16 Quality documentary evidence

6.16.1 Bidders are required to submit evidence that the design and manufacture of the insulators and fittings are in accordance with ISO 9001 and shall include the Capability Statement associated with the Quality System Certification.

6.16.2 If the Bidder is not the Manufacturer, then the documentary evidence shall include the quality system certifications of both the Bidder and the Manufacturer.

6.16.3 Full technical and descriptive details, relating to all the items offered in this enquiry, shall be submitted so the offer can be fully evaluated. This shall include:

(1) Drawings.

(2) Material composition, including filler materials.

(3) Details of clamping arrangement of end fittings.

(4) Reports on field experience with identical insulators.

6.16.4 Failure to submit such information may preclude further consideration of the bid.

6.17 Packing

6.17.1 All composite insulators shall be wrapped in plastic sleeves and packed in crates in such a way that the weight of the insulators does not rest on the sheds.

6.17.2 All crates shall be indelibly marked with the following:

(1) The Municipality’s order number;

(2) The Manufacturer’s and Supplier's (if they are not the same) trade name or trade mark or both;

(3) The place of manufacture; and

(4) The code name and description of the item.

6.17.3 The packaging shall protect the insulator from the normal handling that can be expected from the point of despatch to the point of construction.

6.17.4 Any special handling requirements shall be clearly specified to Employer (the Purchaser) before delivery and shall be clearly specified on the packaging.

6.17.5 The packaging shall be capable of protecting the insulators for sustained periods in storage. The Contractor/ Manufacturer/ Supplier (whoever is directly responsible for the supply to the Employer) shall notify the Employer (Purchaser) of any special methods recommended for storage before delivery and on packaging materials.

6.17.6 The packaging shall not disintegrate due to any wetting and drying that may occur during the installation process on site.

6.17.7 The Contractor shall, at his expense, and at the Employer's discretion, replace insulator units that are damaged during transit due to the delivery negligence. The Contractor/ Manufacturer/ Supplier (whoever is directly responsible for the supply to the Employer) shall, at his expense, at the Employer's discretion, replace insulator units that are damaged due to unsuitable packing. This includes the chipping of glazed surfaces.

6.17.8 If insulators are packed in boxes or crates on pallets, the gross weight of the pallets shall not exceed 1800 kg.

6.17.9 Pallets shall be suitable for handling by fork lift trucks, capable of two-way entry and be reversible.

6.18 Samples

6.18.1 Bidders shall submit samples of the items offered within a week of request by eThekwini Electricity.

6.18.2 The samples shall be delivered to eThekwini Electricity, HV Lines Building No.11, 11 Electron Road (off Umgeni Road), Springfield, Durban, South Africa or as specified at the time of delivery.

6.18.3 Bidders are required to note that bid documents must NOT be included in parcels containing samples.

6.18.4 The Municipality reserves the right to submit samples for such tests as deemed reasonable and necessary.

6.18.5 Unsuccessful bidders situated within the Durban Metropolitan area shall collect and remove their samples within one month of being notified that their bids have not been successful, failing which they will be deemed to have waived all rights to the samples and such samples not collected after one month from the date of such notification will become the property of the Municipality for disposal at its discretion.

6.18.6 Unsuccessful bidders situated within the Republic outside the Durban Metropolitan area may have their samples returned to them at their request, expense and risk. Confirmation of this must be stated in the bid document.

6.18.7 Where a bid is accepted for the supply of goods according to a sample submitted by the bidder, such sample will become the contract sample and will be retained by the Municipality for the duration of the contract, after which the sample may be returned at the request of the Contractor, with the expense of returning to be for the Contractor's account.

6.19 Health, safety and environmental issues

6.19.1 The Bidder shall submit details or a list of:

(1) All materials used in the product, including packing and packaging, and associated chemical data sheets.

(2) Whether the product poses any health or safety risks to persons handling the product. In addition, if there are risks, provide details of the protective gear required to handle the product, e.g. leather gloves.

(3) How the product should be stored and its shelf life.

(4) How the product should be disposed of at the end of its useful life or in the event of failure.

(5) Whether any toxic by-products are produced (whether in gaseous, solid or liquid form) in the event of the product being exposed to fire or heated to elevated temperatures.

(6) Any other pertinent and relevant information relating to health, safety, and environmental issues.

(7) The percentage of the product which can be recycled.

6.20 Handling

6.20.1 Handling, storage and precautionary installation equipment and information shall be made available for insulator products offered on request.

7.0 Fittings and Assembly Hardware

7.1 General

7.1.1 This specification covers the technical and associated requirements for hardware components for support of phase and earth conductors, including support of OPGW in AC overhead transmission power lines rated 132 kV and 275 kV.

7.2 Normative references

Document No.	Document Title
IEC 61284 / SANS 61284	Overhead lines- Requirements and tests for fittings
IEC 60120 / SANS 60120	Dimensions of ball and socket couplings of string insulator units.
IEC 60372	Locking devices for ball and socket couplings of string insulator units: Dimensions and test.
SANS 60471 / IEC 60471	Dimensions of clevis and tongue couplings of string insulator units.
BS 3288 Part 2	Insulator and conductor fittings for overhead power lines, Part 2- Specification for a range of fittings.
SANS 1700	Fasteners
DIN 7990	Steel hexagon head bolts for structural steel bolting, for supply with hexagon nuts.
SANS 1190	Malleable Iron castings.
SANS 121 / ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles-specifications and test methods.
OHS Act, 85 of 1993, as amended	Occupational Health and Safety Act 85 of 1993, as amended, incorporating the 2014 Construction Regulations. Published by South African Government Press, under auspices of the Department of Labour

7.3 General requirements

7.3.1 The standard assemblies for suspension and tension sets are provided in drawings, and the fitting sizes shall match the sizes of the ball and socket or clevis and tongue from the insulators.

7.3.2 Any variation in requirements from the standard drawings for specific lines shall be indicated in the **Technical (Returnable) Schedules**.

7.3.3 All parts shall be new and of the highest class and shall be furnished uniformly in quality and smoothly on the surface in conformity to the best commercial practice without any harmful defects such as flaws, ruts, air holes, cracks, burrs and rough edges, etc.

7.3.4 Filling or plugging of any defective parts shall not be permitted. The design shall avoid sharp corners or projections, which will produce high electrical stress on normal operation.

7.3.5 The design of adjacent metal parts and contacting surfaces shall be so made as to prevent corrosions of the contact surfaces to maintain good electrical contact under service conditions.

7.3.6 The failing loads of all clamps and fittings shall match those of the associated insulators. **The maximum working loads multiplied by a safety factor of 3 shall not exceed these failing loads**. The factor of safety of the fitting when supporting the maximum working load shall not be less than the figure stated in the **Technical (Returnable) Schedules**.

7.3.7 Adequate bearing area between fittings shall be provided and point contacts shall be avoided.

7.3.8 The yield strength of the chosen ferrous material in the final product shall exceed 280 MPa.

7.3.9 All ferrous components shall be hot dipped galvanized.

7.3.10 All stainless-steel components shall be of a grade, condition and design which will not enhance stress corrosion cracking and shall be subject to approval by the Employer's Engineer.

7.3.11 All fittings shall comply with the standard coupling dimensions as per the relevant IEC standards, or other approved standard.

7.4 Corona and radio interference

7.4.1 The design of all line fittings shall avoid sharp corners/ edges or projections which would produce high electrical stress in normal operation.

7.4.2 Particular care shall be taken during manufacture of the fittings and during subsequent handling to ensure that smooth surfaces are free from abrasion.

7.5 Zinc coating

7.5.1 All the iron and steel parts and members shall be zinc coated upon completion of the fabrication. The minimum local galvanizing thickness shall be 85 µm. The Bidder/Contractor shall inform the Employer in writing as to what their capabilities are if this specified thickness is not achievable.

7.5.2 The zinc coating is to be uniform, clean, smooth and free from burrs, sharp edges, lumps and dross so that interconnection parts will fit properly and parts may be assembled and disassembles readily. The zinc coating shall be carried out by the hot dip galvanizing process for all parts.

7.5.3 Threaded parts shall be coated after being threaded and excessive zinc shall be removed from the threads. Nuts and locknuts shall be re-tapped after being coated and shall be capable of being threaded the entire length of threads without use of tools.

7.5.4 The female threads shall be treated with approved rust inhibitor.

7.6 Bolts and nuts

7.6.1 Bolts and nuts shall be hexagon and, in general, meet the requirements SANS 1700 (and DIN 7990 where applicable), except that shank and thread lengths may be non-standard.

7.6.2 Corona free nuts may be furnished, when necessary, for clevis or shackle bolts. At least two sides of each nut shall be flat for a portion of the nut height to permit tightening or loosening of the nut by means of a spanner.

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

7.6.4 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 shall not touch the side of the shackle, or clevis, when run to the end of the threads.

(2) When the nut is backed against the split pin there shall be a maximum of 7 mm between the nut and shackle or clevis for bolts up to and including 25 mm in diameter, or 10 mm for bolts larger than 25 mm in diameter.

(3) The split pin can be freely installed.

7.7 Split pins

7.7.1 Hump back split pins shall not be accepted.

7.7.2 Split pins shall be made of stainless steel suitable for the corrosive coastal environment. The nominal diameter of split pins shall be a minimum of 3 mm for bolts up to and including 19 mm; 5 mm for bolts up to and including 28 mm; and 6 mm for bolts larger than 28 mm.

7.7.3 Split pin holes shall be 0.4 mm to 0.8 mm larger than the nominal diameter of the split pin.

7.7.4 Split pins less than 6 mm in diameter shall have a length of 9 mm to 13 mm longer than the bolt diameter. Split pins 6 mm in diameter shall have a length 16 mm to 19 mm longer than the bolt diameter. The length of a split pin is measured from the underside of the eye to the end of the shortest leg.

7.8 Shackles and clevises

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

7.8.2 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.

7.9 Sag adjusters

7.9.1 When required, sag adjusters with specified maximum connecting length shall be provided. Actual connecting lengths shall be adjustable in approximately 15 mm steps.

7.10 Links

7.10.1 Extension links, (fixed, cranked, and adjustable) shall be provided, subject to approval with respect to sizing and adjustment steps.

7.10.2 Chain link, only where specified, shall be used on suspension assembly for earth conductors.

7.11 Landing plate equilateral triangle

7.11.1 Tension sets shall be fitted with attachment plates (equilateral triangle), where specified, to enable the load on the tension set to be relieved for erection purposes.

7.12 Ball and socket fittings

7.12.1 Dimensions and tolerances of all ball and socket hardware shall be in accordance with IEC 60120, except that the r4 dimension on the pin ball shall be a minimum of 4 mm. All dimensions shall be checked after galvanizing by the gauges specified in the above Specification.

7.12.2 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 IEC 60372-1 shall be met.

7.13 Yoke plates

7.13.1 Yoke plates are required when twin conductors are used. These are used on the suspension assembly and landing span assemblies.

7.13.2 All yoke plates shall have holes for fitting arcing horns or grading rings.

7.14 Arcing horn on phase conductor assembly

7.14.1 Arcing horns shall be provided on the live side of all phase conductor assemblies. The arcing horn shall attach to the hardware and not to the insulator itself. The design of the arcing horns shall be such as to reduce to a minimum damage to the conductors, clamps, insulator strings and arcing horns themselves under all flash-over conditions.

7.14.2 Arcing horns shall be fitted on the earth side of insulator assemblies for the section of line within 1.5 km from a substation.

7.14.3 For twin conductor tension assemblies, where two insulator assemblies are provided, arcing horns shall be fitted on the outer most assembly.

7.14.4 The mechanical strength of arcing horns shall be such that a force of 300 N may be applied to the tip in any direction without causing deformation.

7.15 Arcing horn on earth conductor assembly

7.15.1 Arcing horns shall be provided on the live and earth sides of all insulators. The arcing horn shall attach onto the insulator end fittings. The design of the arcing horns shall be such as to reduce to a minimum damage to the conductors, clamps, insulator strings and arcing horns themselves under all flash-over conditions.

7.15.2 Bolts and nuts for arcing horns shall be stainless steel suitable for the heavy marine pollution environment.

7.16 Grading rings

7.16.1 Grading rings (also referred to as corona shields) shall be provided on the live side on all 275 kV insulator assemblies.

7.16.2 If specified in the **Technical (Returnable) Schedule**, combined arcing horns/ grading rings shall be provided.

7.16.3 For twin conductor tension insulator sets, where two insulators are provided, combined arcing horns/ grading rings shall be mounted on the outer insulator set but the centre line of the arcing horn/ grading ring shall coincide with the common centre line of the two insulator units.

7.16.4 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 rings, stainless steel bolts shall be used.

7.16.5 The rings shall be capable of sustaining a man load of 2 kN.

7.16.6 Special attention is to be paid to the smooth finish so as not to enhance corona.

7.17 Turnbuckles

7.17.1 Turnbuckles shall be provided in reversed low duty tension sets, which are used at landing spans, and low duty spans between gantries. Apart from landing spans or slack spans, line conductor fittings shall not employ screw threads loaded in tension.

7.18 Suspension clamps

7.18.1 The suspension clamp for the phase conductor shall be the bolt-type and that for the standard earth conductor shall be of the cradle bolt type. The body shall be aluminium alloy or malleable cast iron. Cast iron suspension clamps shall be hot dip galvanized and shall be provided with pure soft aluminium liners to protect the aluminium alloy conductors.

7.18.2 The clamp body shall be so made as not to deform the conductor and loosen the individual strands of the conductor. The clamp shall allow the complete conductor to slip before failure of the clamp.

7.18.3 The supporting groove shall be curved in the vertical plane. It shall also be sufficiently curved at the mouth to allow for the conductor to leave up to the maximum departure angle. The mouth shall be flared in the horizontal direction to accommodate conductor side swing.

7.18.4 All conductor grooves and mouths shall, after galvanizing (where applicable), be smooth and free of waves, ridges or other irregularities.

7.18.5 Suspension clamps for OPGW conductor shall consist of a wire-formed arrangement, such as armour grip suspension clamp, and approved by the OPGW Manufacturer. The clamp material shall be fully compatible with that of the OPGW.

7.19 Tension compression clamp

7.19.1 The tension clamp for the phase and standard earth conductor shall be of the compression type.

7.19.2 The tension clamp shall be aluminium alloy for all aluminium alloy conductors, and mild steel inner and aluminium alloy outer for aluminium conductor steel reinforced.

7.19.3 After crimping, the electrical resistance of the tension clamp must be less than that of the conductor joined thereby with the same length as the tension clamp.

7.19.4 When tension clamps are subjected to the required mechanical tests, no slippage of or damage to conductor shall take place at a load less than 95 % of the ultimate tensile strength (UTS) of the conductor.

7.19.5 The compression clamp shall be provided with jumper tags for the attachment of jumper conductor via terminals (flags), and shall be arranged to give a minimum clearance of 150 mm between jumper conductors and the rim of the live end of the insulator. Jumper terminals shall be of the compression type and when subjected to the required mechanical tests, no slippage of or damage to conductor shall take place at a load less than 50 % of the UTS of the conductor.

7.19.6 The tension clamp for OPGW shall be of the wire-formed arrangement, such as using preformed wire wrap, protective rods and thimble-clevis, and approved by the OPGW Manufacturer. The clamp material shall be fully compatible with that of the OPGW.

7.20 Trunnion clamp for post insulator

7.20.1 Trunnion clamps shall be used on line post insulators to support the jumpers and at the same time allow for flexibility in movement of the conductor.

7.21 Fittings tests

7.21.1 Heat cycle and corona type tests of all types of insulator sets shall be carried out in accordance with IEC 61284.

7.21.2 Tensile tests shall be carried out, approved by the Employer's Engineer, to demonstrate that the fittings have a tensile strength not less than that specified in this specification, without showing any signs of failure.

7.22 Joint and tension clamp tests

7.22.1 Samples of all joints, clamps and fittings shall be submitted for examination and all assembly, cutting off of conductor and any work whatsoever necessary for the assembly of the clamps and joints in the field shall be carried out in the presence of the Employer's Engineer with the erection methods and tools proposed for field use.

7.22.2 Tensile tests shall be carried out, approved by the Employer's Engineer, to demonstrate that the joints and clamps have a tensile strength not less than that specified in this specification, without showing any signs of failure or conductor slip.

7.22.3 Electrical tests shall be carried out in accordance with IEC 61284 and approved by the Employer's Engineer, to demonstrate that all types of joints and clamps to be used on this contract have lower resistivity, higher continuous load rating and higher through fault rating than the associated conductor.

7.22.4 The costs of these tests shall be included in the price of the fittings to be tested. Where type tests have previously been carried out on the fittings offered, test certificates shall be provided with the bid.

8.0 Erection

8.1 General

8.1.1 This specification covers the requirements for construction work on site, including environmental management requirements.

8.2 Environmental management

8.2.1 The Contractor shall give or provide all necessary superintendence during the execution of the works. The Contractor or a competent and authorized appointee approved in writing by the Employer's Engineer (which acceptance may at any time be withdrawn) shall be on the works at all times when work is being performed or when the Employer shall reasonably require it. The Contractor shall employ only such persons that are competent, efficient and suitably qualified with related experience in the environmental field. The Employer shall be at liberty to object to and require the Contractor to remove from the works any person, who in the Employer's Engineer's opinion, misconduct's himself or is incompetent in the proper performances of his duties.

8.2.2 All site works required under this contract shall comply with the associated environmental impact assessment, basic environmental assessment, management specification and plan, whichever are relevant.

8.2.3 Payment for the establishment of access to tower sites i.e. the clearing of vegetation, the removal of thereof, the construction of access roads, the construction of erosion control berms and the stock piling of top soils, shall be made using the applicable unit rates quoted in the **Price Schedules (Bill of Quantities)**, or alternatively as a reimbursable expense where rates do not exist, or a combination of both.

8.2.4 Payment for the construction of foundations, the erection of towers and fittings and the stringing of conductors up to completion of the power line as well as any dismantling of existing power lines or parts thereof shall be made at the specific unit rates for these items quoted in **Price Schedules**. These prices shall include for all precautions and methods required to satisfy the environment management plan which are associated with those activities.

8.2.5 Payment for the rehabilitation of tower sites and access roads shall be made at the specific unit rates quoted in the **Price Schedules**, or alternatively as a reimbursable expense where rates do not exist, or a combination of both.

8.2.6 The cost of compliance with the Environment Management Specification and Plan associated with the Contractor's Site Camp and Site Works shall be included in the price for installation work.

8.3 Setting out

8.3.1 The Contractor shall be responsible for the setting out of the transmission line, including route, foundations and towers.

8.3.2 The Contractor shall determine the alignment and co-ordinates of all terminal and bend points, unless issued by the Employer, and shall prepare a longitudinal profile of the centre line of the route.

8.3.3 The route shall be pegged on the centre line by means of Ø16 mm x 750 mm steel pegs positioned every one kilometre or a smaller distance as necessary to ensure inter-visibility between intermediate points.

8.3.4 Every tower centre position shall be marked with a 16 mm diameter steel peg, 1.2 m high and painted white. The pegs are to carry a tag showing the tower number, tower type and height. The pegs are to be left in position until the tower is assembled.

8.3.5 Each bend point shall have five pegs, i.e. one bend point peg and four reference pegs. The bend point peg shall be driven into the ground and secured with concrete. Two reference pegs shall be placed in each of the line directions. One reference peg shall be placed on the angle bisector at a recorded distance from the centre peg. One reference peg shall be placed at any convenient location and recorded. The reference steel pegs shall be 16 mm diameter and at least 750 mm long and shall be driven into the soil leaving 50 mm protruding above ground.

8.3.6 Tolerances in survey and setting out measurements shall be as follows:

Item	Description	Tolerance
1	Allowable error in longitudinal measurement between kilometre pegs	0.05%
2	Allowable accumulated error between line route bend points	0.1%
3	Allowable error in angular measurements	0.5 minutes
4	Allowable error in setting out a bearing	5 minutes of arc
5	Allowable error in relative elevation of ground line	0.5 m
6	Allowable mean error in elevation of distance of 30 m	0.3 m

8.3.7 The Contractor shall, subject to approval by the Employer's Engineer or his authorised Representative, clear all vegetation and bush as deemed necessary for the survey and setting out.

8.4 Bush clearing and relocation of services

8.4.1 The Contractor shall identify all obstructions or hindrances in the form of vegetation, structures, communication lines, other power lines within the servitude for the purposes of construction work.

8.4.2 Unless otherwise specified, bush clearing to ensure compliance to minimum clearances and for construction access shall be done by the Contractor, subject to approval by the Employer's Engineer, at the unit rates in the **Price Schedules**, or alternatively as a reimbursable expense where rates do not exist, or a combination of both, as may be agreed upon. This shall be done in accordance with the Environmental Management Plan.

8.4.3 The Contractor shall mark, in an approved manner, all trees, which in his option, need to be felled or lopped in order to maintain the necessary clearances. Any such clearing will be done in accordance with the Environmental Management Plan or guidance from and approval by the relevant authorities or an Environmentalist.

8.4.4 Clearing of any access roads or tracks for temporary storage areas or camps will be entirely the responsibility of the Contractor and at his own expense.

8.4.5 The removal or relocation of other services, should this be necessary, shall be performed by the responsible authorities, the cost of which will be for the account of those authorities or Employer, whichever is applicable. Where the cost is to be borne by the Employer, the cost shall be submitted to the Employer's Engineer for approval prior to the commencement of such work.

8.5 Foundations

8.5.1 General

8.5.1.1 Once the Contractor has received the written acceptance of the foundation selection by the Employer's Engineer, the Contractor may start with the construction of the foundations.

8.5.1.2 The Contractor shall be responsible for ascertaining that the selected foundations that are installed are suitable for the specific soil conditions. The Contractor shall be responsible for any subsidence or failure due to, in the opinion of the Employer's Engineer, insufficient care having been exercised during the soil investigation or foundation selection.

8.5.1.3 The scope for construction of foundations shall include all excavation, installation, backfilling of excavated material and the removal of all excess material or rubble from the site for disposal at an approved dumping site.

8.5.2 Foundation excavation and placing of the rebar and embedded structural steel

8.5.2.1 The first step is to excavate the foundation cavity required for the selected foundation in the correct position. In the case of surface cavities, the Contractor shall first excavate and stockpile the topsoil from the foundation area. Thereafter the Contractor shall excavate the subsoil and stockpile it separately from the topsoil.

8.5.2.2 The excavated material should be stockpiled at least 2 metre away from the excavation's edge to prevent possible collapse of the excavation side walls. During the total duration of the foundation construction the Contractor should be sensitive for any possible side wall collapse in order to protect all personnel. If the side walls are inclined to collapse, they should either be shored or sloped to the angle of repose.

8.5.2.3 In order to ensure that the contact surfaces between the concrete and soil are firm, the foundation should be constructed immediately (as soon as possible) after the excavation is completed. If there is any loose material, the loose material should be removed and the volume back-filled with 10 MPa concrete. The cost of the back-fill concrete due to unavoidable loose material shall be for the Employer's account, subject to approval by the Engineer. If there is any over-excavation, this shall be back-filled with 10 MPa concrete. The cost of the back-fill concrete due to over-excavation is for the Contractor's account. Under no circumstances may these over-excavations be back-filled with soil or rock.

8.5.2.4 All foundation excavations are to be adequately protected by a barrier or fence from the beginning until the backfilling procedure is completed to prevent any persons or animals from accidently falling into the excavation.

8.5.2.5 Written approval for the use of explosives for the excavation of foundations shall be obtained from the Employer's Engineer. The Contractor shall be responsible to comply with all the rules and regulations concerning the use of explosives. The Contractor shall be responsible for the safety of all personnel, site works, and persons or property in the vicinity of the explosion. The Contractor shall rectify damage caused by these explosions and these expenses shall be for the Contractor's account. The Contractor's insurance policy for this contract shall cover the use of explosives, whether or not the explosives are used by the Contractor or his Subcontractor.

8.5.2.6 If additional excavation over and above that required for the construction of standard foundations for the various soil types (including removal of excess material) is required due to ground slope and if approved by the Employer's Engineer, this shall be carried out at the unit rates quoted in the **Price Schedules,** or alternatively as a reimbursable expense where rates do not exist, or a combination of both.

8.5.2.7 The Contractor should request the Employer's Engineer to check and accept the excavation, before starting with the placing of the reinforcing steel and the leg stub in the excavation.

8.5.2.8 If the subsoil on the floor of the excavation is very weak or submerged, the excavation should be deepened by 75 mm and a bedding layer of 10 MPa concrete 75 mm thick must be placed prior to the construction of the actual foundation. If the foundation floor is submerged a sump should be dug

in the lowest corner and the water shall be pumped out until the casting of the concrete has been completed and the concrete has hardened. The bottom steel reinforcing should be placed in the excavation on top of 100 mm thick cover blocks to ensure a minimum concrete cover of 75 mm to 100 mm. The leg stub should be placed on top of a concrete block of 300 x 300 x 100 mm in the centre of the pad.

8.5.2.9 The stub should be aligned to ensure the correct slope and position to the other legs to ensure that the tower can be properly erected. The top end of the stub is held firmly in position by two adjustable poles perpendicular to one another that are firmly anchored at their free ends to ensure that the position of the top end of leg stub is firmly fixed. The bottom end of the stub should be firmly fixed to the steel reinforcing to ensure that the stub does not change its position at any time during the construction of the foundation. Embedded structural steel shall have a minimum cover of 80 mm and the steel reinforcement shall have a minimum cover of 75 mm.

8.5.2.10 The reinforcing steel shall be tied with no less than 1 mm diameter annealed wire at all intersections in order to fix the position of the steel reinforcing during the concrete placement. The stub shall be properly earthed to the steel reinforcing in the pad by means of a flexible tail bolted to the stub and connected to the reinforcing steel by means of suitable PG clamps. The rebar shall be thoroughly cleaned at the connection point.

8.5.2.11 The leg stub cleats shall be designed assuming the total leg force is transferred by means of cleats only to the concrete with a 10 MPa contact pressure with the concrete.

8.5.2.12 Prior to the placing of the concrete, the Contractor should inform the Employer's Engineer that the rebar is ready for inspection. This is a holding point and no concrete may be cast before the rebar and earthing of the foundation has been inspected and accepted in writing by the Employer's Engineer. Formwork should also be placed in such a manner that the steel reinforcing has sufficient cover and where it joins a previously cast concrete section, the construction joint between the old and new concrete should be properly prepared as specified in SANS 10100-2. Under no circumstances may there be a concrete construction joint in the cap of a rock anchor or pile except where the rock anchors or piles are joined to the cap. These caps shall be cast in a single operation. All formwork shall be of adequate strength for proper vibration of the concrete. All formwork contact surfaces should be pre-treated with a concrete release agent prior to installing of the formwork.

8.5.2.13 The Construction Regulations pertaining to Formwork and support work and Excavation work will be applicable.

8.5.3 The placing of concrete

8.5.3.1 The concrete used should have a minimum compressive strength of 25 MPa after 28 days and target strength of 35 MPa, with a maximum water: cement ratio of 0.555 and the minimum cement content shall be 340 kg/m^3. The 28-day cube strength may not fall below 85 % of the minimum compressive strength. The concrete shall be placed on site within 90 minutes after adding water to the cement and aggregate mix at the mixing plant. When the concrete arrives at the foundation position the slump of the concrete shall be measured in accordance with SANS 5862-1 to verify that it is still workable and the value recorded. If the slump is too low the mix shall be rejected.

8.5.3.2 Four concrete cube samples shall also be manufactured from each batch initially (later when satisfied with the overall concrete quality from one random selected batch in the morning and one randomly selected batch in the afternoon) and cured and tested in accordance with SANS 5863. One cube will be tested after 7 days and two 28 days after construction. The fourth cube is used as a spare.

8.5.3.3 If the concrete takes longer to be placed than 90 minutes, a retarder accepted by the Employer's Engineer may be added to the concrete in order to extend the allowable concrete placing period. If the exposed surfaces of the foundation excavation against which the concrete is to be cast are dry, these surfaces shall be moistened just prior to casting in order prevent excessive moisture loss from the concrete mix due the water being sucked from the concrete by these dry surfaces.

8.5.3.4 If the air temperature is 7°C and falling or 3°C and rising, concreting may still be done provided the concrete reaches a minimum strength of 5 MPa before the air temperature drops below 5°C. The temperature of the concrete mix may be increased by heating the water-plus-aggregate mix before adding the cement, provided that the cement is not added to the mix if the temperature of the water-plus-aggregate mix is above 30°C. If the air temperature is above 30°C no concreting may take place unless the temperature of the mix immediately before placing on site is less than 30°C. The concrete mix temperature just prior to placing shall be recorded for each mix. In hot weather the concrete mix may be cooled down by storing the aggregate in the shade and using iced water. In hot dry weather the exposed surfaces of freshly poured concrete should be covered with plastic sheets immediately after placing in order to prevent rapid moisture loss from the concrete mix during initial set which leads shrinkage cracks forming.

8.5.3.5 All concrete shall be vibrated vertically during placing to rid the concrete of voids and compact the concrete properly. Maximum stone size for concrete aggregate shall be 37.5 mm. Maximum fine aggregate size shall be 4.75 mm. Fine aggregate shall be coarse, sharp and clean from dust, salt, clay and organic material. Fine sand of uniform grain size shall not be used. Mixing water shall be clean, free from earth and organic material, and shall not contain any acids or alkalis in suspension. The aggregate will be assessed in accordance with SANS 1083.

8.5.3.6 For anchoring of rock anchors a grout mix is used which has a minimum strength of 35 MPa in 28 days. Epoxy grouts may only be used with the approval of the Employer's Engineer. Maximum aggregate size is 13.2 mm.

8.5.3.7 Once the placing of the concrete is complete, and initial set of the concrete has taken place, all exposed concrete surfaces should either be covered with plastic sheeting, or continually sprayed with water for 10 days or treated with a concrete curing compound to prevent moisture loss from the concrete in order ensure proper strength gain of the concrete. The formwork should be kept in place for at least 36 hours in order for the concrete to gain sufficient structural strength before the removal of the formwork. Once the formwork has been removed the new exposed concrete surfaces should also be treated with a concrete curing compound in order to ensure proper strength gain of the concrete.

8.5.3.8 Excess concrete may only be dumped at an approved waste site and the water used to clean the drums of the delivery trucks may only be dumped into a cavity formed in subsoil to be used for backfilling. All methods of disposal are subject to the approval of the Employer's Engineer.

8.5.3.9 Unless approved by the Employer's Engineer, construction joints will not be permitted. If construction joints are unavoidable, the procedure for ensuring their integrity shall be approved by the Employer's Engineer.

8.5.4 Backfilling of the foundation excavation

8.5.4.1 Once the formwork has been removed the backfilling operation of the excavation may start. Backfilling and compaction shall be done in layers of 225 mm maximum. The bottom 225 mm layer should consist of soil with maximum particle size of 19 mm. The layers following thereafter may not contain any particles larger than 150 mm. The subsoil backfill material shall be free from organic material such as trees, brush, scraps, etc. Backfill material shall be moistened to its Optimum Moisture Content (OMC) in order to ensure that the material is compacted properly to at least 90% of the in-situ density. The surface of the backfill around the exposed section of the foundation shall be carried to such an elevation that no ponding takes place on top of the foundation. The very top layer shall consist of top soil in order to re-establish the vegetation of the natural surface. Any remaining subsoil material should be removed to an approved waste site. The two temporary stub supports of the top end of the leg stub may only be removed once the backfilling operation is complete.

8.5.4.2 Back-filling and ramming of earth shall be done thoroughly and evenly around all parts of each foundation. Back-filling from one side or corner only of an excavation will not be allowed. The back filling material shall be compacted in layers not exceeding 300 mm in depth and the final density shall not be less than 1600 kg/m^3.

8.5.4.3 Where the excavated material is unsuitable for backfilling, and if approved by the Employer's Engineer, this material must be removed from site and replaced with imported backfill material of approved quality, at the unit rates in the **Price Schedules**, alternatively as a reimbursable expense where rates do not exist, or a combination of both. The disposal methods and locations of removed subsoil shall be approved by the Employer's Engineer prior to disposal.

8.5.5 Rock anchors and pile foundations

8.5.5.1 Rock anchors or piles shall be reinforced over their entire length in order to transfer the applied axial forces to the rock or soil and the reinforcing extends into the anchor cap or pile cap sufficiently and is suitably anchored to ensure full transferal of the vertical leg forces to the rock anchors or piles. The anchor cap or pile cap shall be reinforced to withstand the shear and bending forces applied by the embedded leg stub. The rock anchor reinforcing shall be debonded by a method acceptable to the Employer's Engineer for a length of 100 mm above and 300 mm below the anchor cap base.

8.5.5.2 A structural anchor/pile cap of reinforced concrete shall be used to transfer the workloads from the leg stub to the foundation cap

8.5.5.3 The use of grout mixes, including proprietary mixes, must be accepted by the Employer's Engineer prior to its use. Documented evidence of use in similar applications, which have been accepted by a recognized authority, shall be submitted as proof of its suitability.

8.5.5.4 All drilled anchor/pile holes shall be checked carefully for fouling or water and cleared before the reinforcement or concrete is placed. The concrete of the rock anchors/piles shall continue at least 150 mm above the anchor/pile cap base. The hardened concrete of the anchors/piles shall be chiselled back to 75 mm above the anchor/pile cap base. Just before casting the cap the exposed concrete surfaces of the anchors or piles shall be prepared according to SANS 10100-2 to ensure proper bonding between the old and fresh concrete. In the case of weak soil, the pile cap base depth shall be lowered by 75 mm and a 75 mm thick layer of 10 MPa bedding concrete placed before constructing the pile cap. Proper provision should be made to ensure that the tower loads are transferred from leg stub to the anchors/piles in the cap.

8.5.6 Rock anchor and pile test requirements

8.5.6.1 Prior to the actual construction of any rock anchor and/or pile foundations, the Contractor shall, if so instructed by the Employer's Engineer, install in each general soil or rock type encountered, and at any additional locations on the project site selected by the Employer's Engineer, a test pile and/or rock anchor for the purpose of verifying the concrete/soil or grout/rock frictional resistance values. These test piles and/or rock anchors shall not form part of any final foundation.

8.5.6.2 The Contractor shall prepare the test procedure and supply all test equipment and personnel to perform these tests. All test piles and/or rock anchors shall be tested to failure of the piles and/or rock anchors. The pile and/or rock anchor test procedure, shall be prepared by the Contractor and shall be submitted to the Employer's Engineer for acceptance prior to any tests.

8.5.7 Test requirements

8.5.7.1 The test beam shall be supported outside the uplift influence zone of pile or rock anchor to be tested and the distance from the pile or rock anchor to inside of the test beam supports shall not be less than 'r' where:

$r = (L + c) \tan\varphi$

Where:

L = depth of pile or rock anchor with respect to the underside of pile or rock anchor cap.

c = depth of pile or rock anchor cap excavation

φ = frustum angle

8.5.7.2 The maximum design load shall be applied to the test pile or rock anchor during the test in appropriate increments to 50%, 75% and 90% of the design load, applying each load increment for a minimum holding period of 5 minutes and finally, 100% for at least 30 minutes. Successive load increments shall not be applied and the maximum test load shall be held back until the rate of movement under the acting load has stabilized at a rate of movement of less than 0.5 mm in 5 minutes for piles and 0.2 mm in 5 minutes for rock anchors.

8.5.7.3 Piles will be considered to have passed the test provided the total pile movement does not exceed 5 mm during the entire test up to and including the maximum design load. Rock anchors will be considered to have passed the test provided the maximum movement of the rock anchor does not exceed 2 mm during the entire test up to and including the maximum design load. The residual movement once the load has been removed totally, must be recorded before testing the pile or rock anchor to failure load.

8.5.7.4 One micro-meter shall be mounted on each side of the pulling rod, in order to eliminate deformation errors due to the rotation of the pile or rock anchor. The frame holding these micro-meters in position shall also be supported at a distance of at least 'r' away from the pile or rock anchor. The average reading of the two micro-meter readings will represent the actual creep for a particular load. Should this method, for any authentic reason prove impractical, a suitable alternative method may be used.

8.5.7.5 Pile or rock anchor tests shall be conducted in the presence of the Employer's Engineer. When the test is completed, the test pile or rock anchor shall be removed by the Contractor for examination, and properly disposed of, or cut off at least 600 mm below NGL and backfilled, or as directed by the Employer's Engineer. Pile or rock anchor foundations constructed on site by the Contractor, prior to acceptance of the pile and/or rock anchor test results by the Employer's Engineer, will be subject to modification or replacement by the Contractor, should these piles or rock anchors fail the test.

8.6 Towers

8.6.1 Tower material handling and storage

8.6.1.1 Tower steel in storage shall be blocked off the ground with a sufficient number of blocks to prevent bending or warping of individual members.

8.6.1.2 Tower steel shall be handled with the use of nylon or fabric slings. The use of unprotected wire rope slings is not permitted.

8.6.1.3 Material shall not be dumped or dropped from trucks, but shall be carefully unloaded and stacked.

8.6.1.4 Material shall not be dragged on the ground.

8.6.2 Assembly and erection

8.6.2.1 Towers shall be assembled and erected in strict accordance with the applicable drawings and national regulations utilizing suitable construction equipment, tools and procedures.

8.6.2.2 Proper precautions shall be taken to ensure that the towers are not strained or damaged in any way during erection.

8.6.2.3 Special care shall be taken not to injure the skin of galvanized or specially treated surfaces during erection. Care shall be taken to prevent or remove any rust streaks or foreign matter deposited on galvanized surfaces during storing or transport or after erection.

8.6.2.4 Towers shall be erected on reinforced concrete foundations which have set and cured for at least 14 days. All towers shall be vertical within a tolerance at the tower top of 0.3% of the total tower height before installation of conductors.

8.6.2.5 Assembly or erection procedures shall not cause tower members, stubs or foundations to be overstressed. Where tower assemblies are not sufficiently rigid, suitable bracing shall be provided.

8.6.2.6 Contact surfaces shall be cleaned of dirt or foreign material before assembly. Wherever possible, bolts shall be assembled on main chords and trusses with nuts on the outside and heads on the inside of the members. Bolts assembled on members with horizontal surfaces shall have heads down and nuts up.

8.6.2.7 Although some drifting may be allowed in the assembly of tower members, the driving of bolts to correct mismatched holes shall not be permitted.

8.6.2.8 Mis-fabricated parts may not be repaired in the field without the approval of the Employer's Engineer. No repair work involving bending shall be done in the field.

8.6.2.9 Where drilling, punching or clipping is done in the field, all exposed steel surfaces shall be coated with an approved heavy layer of zinc-rich paint or an accepted equivalent.

8.6.2.10 Suitable ladders shall be used wherever necessary during erection of towers. Such ladders, and any temporary step bolts shall be removed when erection work is not in progress.

8.6.2.11 After final tightening of all nuts, each nut shall be secured in position by punching four indentations symmetrically around the exposed threads with a round pointed centre punch. The nuts and exposed bolt thread shall be painted with a suitable calcium plumbate based galvanized iron primer.

8.6.2.12 The Contractor shall install tower labels.

8.6.2.13 The Contractor shall install all step bolts and anti-climbing devices.

8.6.2.14 After erection, all towers shall be cleaned of all foreign matter or surplus paint.

8.6.3 Tower footing resistance measurement

8.6.3.1 Before earth conductors are erected, the Contractor shall measure the electrical resistance to earth of all towers using a high frequency tester that does not require disconnection of the shieldwire/ earthwires, and record the temperature, soil type and soil condition, amount and severity of rain (in mm) up to 3 days prior to the test.

8.6.3.2 Should the values be higher than the specified values, the Contractor shall install additional earthing.

8.6.3.3 All measurement values shall be provided to the Employer's Engineer.

8.7 Conductors, insulators and fittings

8.7.1 General

8.7.1.1 This section covers the stringing of phase and earth conductors, which includes the assembly and installation of the insulator, hardware and related accessories.

8.7.1.2 The assembly makeup shall be as follows, unless otherwise specified:

(1) Suspension points for both single and twin conductors shall use insulator assemblies consisting of single longrod units.

(2) Strain points on line spans for single conductors shall consist of single normal tension longrod units. Strain points on line spans for twin conductors shall consist of twin normal tension longrod units.

(3) Strain points on landing spans for both single and twin conductors shall use insulator assemblies consisting of single light duty longrod units.

8.7.1.3 The stringing of OPGW conductor shall be directly supervised by a Specialist, the details of whom shall be provided in the **Resource Schedule**. Joint positions for OPGW shall be approved by the Employer's Engineer. The Contractor shall ensure that all clamps and fittings used on OPGW conductor are approved by the Manufacturer of the OPGW conductor. Reference shall also be made to the OPGW Specifications.

8.7.2 Material supply

8.7.2.1 The Contractor is to establish the correct quantities of all materials required before stringing commences.

8.7.2.2 A nominal amount (dependent on the terrain; max. 3 %) of phase and earth conductor may be allowed for sags, terrain variations and jumpers. Off-cuts (not used for jumpers) and waste shall be for the Contractor's account.

8.7.3 Crossings, notices and permits

8.7.3.1 At crossing of roads, other power lines, railways and communication lines, the provisions of the Occupational Health and Safety Act, No. 85 of 1993, as amended, shall be compiled with, or other measures as shall be approved. The cost of this shall be for the Contractor's account, unless specifically stated that it is for the Employer's account in the Scope of Work and/or **Price Schedules**. If such is stated, then the payment shall be made using the unit rates quoted in the **Price Schedules**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

8.7.3.2 Temporary conductor supports shall be used, or equally effective measures taken, to prevent encroachment of statutory clearances, or other clearance requirements stated in the permits, between the conductor being strung and other power or communication lines, roads or railways being crossed.

8.7.3.3 Where specific requirements for crossing obstructions are detailed in the **Technical (Returnable) Schedules** or detailed in the Environmental Management Plan or pointed out during the route inspection or are indicated in drawings issued with this specification, the cost of these requirements shall be included in the installation (erection) price of the associated equipment. Otherwise, the Contractor shall be compensated using the unit rates quoted in the **Price Schedules**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

8.7.3.4 Where special arrangements have to be made by a service authority to accommodate the crossing of their service, all arrangements for this shall be made by the Contractor, and shall be paid for by the Contractor. The Contractor will be reimbursed upon providing proof thereof. No mark-up of these costs by the Contractor will be permitted.

8.7.3.5 Payment for any special plant, equipment (e.g. gum pole H-frames or cradle guards) and/or activity required for the erection of conductors over crossings, unforeseen services or obstructions shall be made using the applicable unit rates quoted in the **Price Schedules**, alternatively as a reimbursable expense where rates do not exist, or a combination of both.

8.7.3.6 Suitable structures under each phase will be erected to protect all fences from conductor damage during stringing.

8.7.3.7 Temporary changes in poles, fixtures or conductors of lines being crossed will only be carried out if accepted by the Employer's Engineer. The Contractor shall indicate any changes considered necessary and the Employer's Engineer will co-ordinate any changes with the owner of the service.

8.7.3.8 The Contractor shall notify the Employer's Engineer, at least 30 days in advance, of the time he intends to make crossings of power lines, communication lines, major roads or railways. This notification shall state the location of the crossing to be made, the approximate time of the permit, the length of time that will be required to affect the crossing, and the duration of permit requested.

8.7.3.9 The Contractor will arrange that all affected crossings be de-energized.

8.7.3.10 The time of line outages shall be kept to the absolute minimum. All preparatory work shall be done prior to the work permit coming into effect. Upon completion of the work, the Contractor shall immediately notify the Employer's Engineer that lines are clear and release his working permit.

8.7.3.11 Special scaffolding may be required at certain crossings. If so, the Employer's Engineer will instruct the Contractor to provide suitable scaffolding and nets.

8.7.4 Handling and stringing of conductors

8.7.4.1 The Contractor shall submit the proposed method of stringing for approval.

8.7.4.2 All phase and earth conductors shall be tension strung. The fullest use possible shall be made of the maximum conductor lengths in order to reduce to a minimum the number of conductor joints. All instances where tension joints are used shall be approved.

8.7.4.3 The equipment and methods used for stringing the conductors shall be such that the conductors will not be damaged. Particular care shall be taken at all times to ensure that the conductors do not become kinked, twisted or abraded in any manner.

8.7.4.4 Stringing shall be done in daylight hours only.

8.7.4.5 The Contractor shall make suitable arrangements for temporary staying of towers, and anchoring of conductors when necessary. Conductors may not be anchored to any portion of any tower, except strain towers, and then only at the points designed for conductor attachment. Temporary anchoring to footings and guy anchors will not be permitted. Where temporary anchoring is required, suitable temporary anchors shall be provided. Installation and removal of temporary anchors will be the Contractor's responsibility.

8.7.4.6 Matched conductor drums, marked with the same number followed by the suffix A, B, C etc., shall be used for each pull of multiple conductors per phase to ensure even sag characteristics and a minimum number of joints. The Contractor shall select the most suitable sets of matched conductor drums for each stringing position to minimise wastage of conductor. The Contractor shall keep an accurate record of the phase and earth conductor drum numbers and their position.

8.7.4.7 Where multiple conductors per phase are used, these shall be attached to a single running board and strung simultaneously to ensure matched sags. The individual conductors shall be attached to the running board by auxiliary clamps that will not allow relative movement of strands or layers of wire, and shall not over tension or deform individual wires.

8.7.4.8 Running boards shall pass through blocks smoothly without hanging, catching or causing wide variations in pulling tensions, damage to the blocks or over stressing of towers. The pulling line shall be a non-rotating type, which will not impart twist or torque to the running board or conductors. Swivels shall be used to attach the pulling line and conductors to the running board. Swivels shall be small enough to pass through the blocks without damage to either, and shall have ball bearings and be free turning under load.

8.7.4.9 All conductors shall be strung by the controlled-tension method by means of rubber faced, double-bull wheel-type tension stringing equipment. This equipment must be so designed that there shall be

no conduction of the heat generated by the braking action, to the bull wheels. There shall be appropriate mechanical braking on the reels to prevent loose conductor between the reels and the bull wheels, but sufficient tension to pull the conductor in between layers remaining on the reel. Brake controls shall be positive and fail-safe in order to minimise the danger of brake failure.

8.7.4.10 The tension shall be controlled individually on each conductor, and when the desired tension is obtained, the same constant tension shall be held so long as the brakes are left at this setting. Tensions, while pulling, must be sufficient to clear all obstacles safely without damage to the conductor. At no time shall the pulling tension exceed the tension shown on the sag charts. Pulling of more than one drum length of conductor shall be subject to the Employer's Engineer's acceptance.

8.7.4.11 Adequate protection shall be provided where there is danger of conductors being damaged by vehicles or other equipment and objects. Conductors shall not be left in contact with the ground, vegetable matter or any conducting or semi-conducting material. Wood lagging or similar material shall be used to protect the conductor when working at ground level.

8.7.4.12 Radio communications shall be used to relay information and instructions between the conductor tensioning station, intermediate check points, mobile stations and the pulling station at all times during a stringing-tensioning operation. An outage of radio communications at any station will require immediate cessation of conductor pulling operations.

8.7.4.13 The placement of tensioning and pulling equipment shall be such that the vertical angle of pull on a cross-arm during stringing operations shall not be more than 20°. Conductors shall not be pulled around angles that exceed 20°. With tandem-mounted blocks, the pulling angle shall not exceed 40°.

8.7.4.14 The sheaves shall conform to the conductor Manufacturer's recommendation as to diameter, and to size and shape of groove for the size of conductor used. Sheaves shall have a minimum diameter of fifteen times the conductor diameter at the base of the groove. Block surfaces that will be in contact with the conductor shall be coated with neoprene or rubber. This covering shall be kept clean and free of materials that might damage the conductor surface. The conductor sheaves shall have a separate groove for the pulling line. The pulling line shall not run on the rubber covered conductor grooves. The sheaves shall be inspected for damage or contamination before each usage. The Contractor shall not use any sheaves rejected by the Employer's Engineer due to damage or excessive wear. The Contractor shall immediately remove such sheaves from the site.

8.7.4.15 During stringing operations and before regulating, if it becomes necessary to leave the conductor in the blocks for longer than eighteen hours, the conductor shall be left at reduced tension, and the Employer's Engineer immediately notified. The percentage of sag, spans involved, time interval, and correction for creep shall be noted, and records forwarded to the Employer's Engineer. In no case shall conductors be left with less than the following clearances:

(1) Cultivated or open country: 6 metres.

(2) Roads and trails: 8 metres.

(3) Railroad tracks: 9 metres.

8.7.5 Joints

8.7.5.1 Before stringing commences, the Contractor will be required to compress a sample each of phase and earth conductor mid-span joints, as well as a phase conductor dead-end assembly on site in the presence of the Employer's Engineer, using the matched and numbered dies and compressors intended to be used on the line during stringing. The length of conductor between any two fittings on the sample shall be not less than 100 times the overall diameter of the conductor.

8.7.5.2 At an acceptable testing authority a tensile load of about 50% of the breaking load of the conductor shall be applied and the conductor shall be marked in such a way that movement relative to the fitting can easily be detected. Without any subsequent adjustment of the fitting, the load shall be steadily

increased to 95 % of the breaking load and then reduced to 90% of the breaking load and maintained for 1 min. There shall be no movement of the conductor relative to the fitting due to slip during this period of 1 min and no failure of the fitting. The conductor shall then be loaded to failure, and shall again withstand a minimum load of 95 % of the minimum breaking strength of the conductor for it to be deemed acceptable. If the sample fails this test, a further three (3) samples shall be tested and will all be required to pass the above. If any one or more of these samples fail, no stringing shall commence until the Employer's Engineer is satisfied that the equipment is acceptable. A copy of the test report shall be forwarded to the Employer's Engineer, prior to stringing.

8.7.5.3 Only approved coded jointers shall be authorized to make joints on conductors. Tools, equipment and application methods shall be approved for use, by both the Manufacturer/ Supplier of joints and dead-ends, and accepted by the Employer's Engineer.

8.7.5.4 As far as possible, complete drum lengths of conductor and earth conductor shall be used to reduce the number of joints. Joints shall not be closer than 15 metres to the nearest suspension tower or 30 metres from the nearest strain tower. There shall be no tension joints in adjacent spans, in strain sections of less than three spans or in spans crossings railways, proclaimed roads, power or important communication lines or in spans immediately adjacent thereto. In no case shall more than one joint be installed in a given span, nor shall a joint be installed in a span dead-ended at both ends. The minimum distance between joints shall be 300 metres.

8.7.5.5 Whenever joints or dead-ends are made, auxiliary erection clamps and hauling devices shall not be placed closer than 8 m to the point of joint or dead-end. Conductors, joints and clamps shall be erected in a manner such that no bird caging or over tensioning of individual strands of layers or other deformation shall occur. The auxiliary erection clamps shall not allow relative movement of strands or layers of wire, and shall not birdcage, over tension or deform individual wires.

8.7.5.6 The conductor shall be cut with a ratchet or guillotine cutter to produce a clean cut, retaining the normal strand lay and producing minimum burrs. The aluminium strands shall then be stripped from the steel core by using an acceptable stripper. Under no circumstances shall high tensile hacksaw blades be used to cut conductor. Conductors shall be marked with paint, crayon or wax pencil – not by metal objects.

8.7.5.7 The conductor shall be laid out for a distance of 15 m and straightened at the ends before preparation for installation of joints or dead-ends. Compression jointing shall be carried out on a clean tarpaulin or jointing trailer. The lay of wires shall be tightened before the first compression is made. The conductor strands shall be cleaned by wire brushing and an accepted non-oxidizing paste applied. Compression shall be carefully made so that the completed joint or dead-end is as straight as possible. To minimise distortion, the joint should be rotated 180 ° between each compression operation, the joint and conductor being fully supported in the same plane as the compression jaws. If, in the opinion of the Employer's Engineer, the completed joint or dead-end requires straightening, it shall be straightened on a wooden block by use of a sledgehammer and shaper or wooden mallet.

8.7.5.8 All joints and conductor joint faces shall be coated with an approved anti-corrosion electrical joint compound which has metallic particles and operating temperature ≥ 200 ºC, (Alnox EJC or equivalent), so as to also prevent ingress of moisture to the current carrying surfaces.

8.7.5.9 If, in the opinion of the Employer's Engineer, the joint or dead-end has not been satisfactorily straightened or has been damaged in the process, the Contractor shall replace it.

8.7.5.10 After compression has been completed, all corners, sharp projections and indentations resulting from compression shall be carefully rounded. All other edges and corners of the fitting that have been damaged shall be carefully rounded to their original radius. Nicked or abraded surfaces shall be carefully smoothed. Tape, tape residue and filler paste shall be removed from fittings and conductors.

8.7.5.11 Sufficient notification must be given to the Employer's Site Representatives prior to the installation of compression fittings. Unless previously agreed all joints and dead-ends shall be installed in the presence of the Employer's Site Representative.

8.7.5.12 Under no circumstances shall compression joint be allowed to pass the travellers, unless accepted by the Employer.

8.7.5.13 During the progress of the stringing, the Contractor shall keep an accurate record of the spans in which conductor and earth conductor joints are made, the date of assembly onto the conductor. A copy of these records shall be supplied to the Employer's Engineer.

8.7.6 Preparation of metal to metal contact surfaces

8.7.6.1 All current carrying connections, contact surfaces, clamps, conductor and terminals shall be prepared as follows:

(1) Wipe the mating surfaces free from previously applied joint compound, grease and dirt (except the bores of compression sleeves).

(2) Apply 1 mm thick coating of approved electrical joint compound (Alnox EJC or equivalent) to the surfaces using a non-metallic spatula or similar tool.

(3) Scrub all the coated surfaces thoroughly with a wire brush which is new or which has been used solely for this purpose.

(4) Wipe off the joint compound.

(5) Apply a fresh 1 mm thick coating of the electrical joint compound.

(6) After a period of not more than one minute make the connection in the normal manner and remove excess extruded compound. (Note that no compound squeezed out by clamping pressure shall be used in making further joint. The Contractor shall apply such compound as necessary for making the connections by the method outlined above).

(7) Tighten all bolts and U-bolts to their specified torque. (On bolted connections care shall be taken during the tightening to avoid overstressing the bolts or components of the clamps. A torque wrench shall be used for tightening each bolt to the required torque).

(8) Leave clamps for 24 hours to allow aluminium conductor to expand and contract.

(9) Check all bolts to ensure that they are still at the required torque.

8.7.7 Conductor repairs

8.7.7.1 Damage caused by the Contractor shall be repaired in a manner determined by the Employer's Engineer. Damage is any deformity on the surface of the conductor that can be detected by eye or by feel. Damage includes, but is not limited to nicks, scratches, abrasions, kinks, bird-caging, and popped out and broken strands.

8.7.7.2 Depending upon the severity of the damage and the length of damaged section, the repair shall be made by careful smoothing with extra fine sandpaper, covering with preformed repair rods, installing a compression-type repair sleeve, or by cutting and splicing.

8.7.7.3 Kinked, bird-caged or severely damaged sections of conductor shall be cut out. When there is repeated damage in the same span, or in consecutive spans, the entire conductor in such spans shall be replaced.

8.7.7.4 All damage caused by auxiliary erection clamps or other gripping devices shall be repaired or cut out, as instructed by the Employer's Engineer or his representative, before the conductor is sagged.

8.7.7.5 Preformed repair rods shall be installed if no more than one strand is broken, or nicked deeper than one third of the strand diameter, or when a number of strands are reduced in area not exceeding the area of one strand. Not more than two sets of preformed repair rods shall be installed on any one conductor in any given span.

8.7.7.6 A compression-type repair sleeve shall be installed, if not more than one third of the outer strands of the conductor are damaged over a length of not more than 100 mm, or not more than two strands are broken in the outer layer of conductor and the area of any other damaged strands is not reduced by more than 25 %.

8.7.7.7 Compression-type repair sleeves shall not be installed on one conductor in a given span if it already contains a conductor splice, conductor dead-end or another compression-type repair sleeve.

8.7.7.8 Damage to the steel strands or aluminium strands, exceeding the stated limits for repair sleeves, shall be cut out and spliced by means of a compression type mid-span joint.

8.7.7.9 Any foreign matter such as pitch, paint, grease, joint compound placed on the conductor and fittings by the Contractor shall be removed by methods approved by the Employer's Engineer prior to regulating.

8.7.8 Regulating

8.7.8.1 The Contractor shall string all conductors and earth conductors to the appropriate sags and tensions as determined from the conditions specified in the Technical (Returnable) Schedule. The calculation of sag corrections for creep and clamping offsets shall be the responsibility of the Contractor. Such calculations shall be submitted to, and accepted by the Employer's Engineer prior to regulating.

8.7.8.2 To accommodate for creep, conductors shall not be tensioned initially to the critical clearance. An initial tension shall be used that when creep is added, the final tension does not give a sag value that drops the conductor below the critical clearance.

8.7.8.3 The phase and earth conductors shall be regulated with such tensions and sags in still air that at a temperature of -5 °C with the assumed maximum loadings stated elsewhere in this specification, the tension in the line and earth conductors shall not exceed the maximum working tensions of the conductors. In calculating the sags and tensions, allowance shall be made for the elasticity and coefficients of expansion of the conductor materials.

8.7.8.4 Conductors and earth conductors shall be strung to the appropriate sag determined for the actual span length, and the equivalent span of the strain section involved.

8.7.8.5 The ruling/ equivalent span of a strain section is given by the formula

$$Le = \sqrt{\frac{\Sigma L_i^3}{\Sigma L_i}}$$

where L_i is the length of the individual spans in the strain section. The sag Se for the equivalent span Le, is the sag determined from the conditions specified, i.e. appropriate conductor temperature. The correct sag S for any actual span length L in a strain section of equivalent span Le is then given by:

$$S = \left(\frac{L}{Le}\right)^2 \times Se$$

8.7.8.6 The Contractor shall supply initial and final Sag and Tension table of values for the specified conductor based on the Stress-Strain and Creep test for the conductor supplied, unless it is specifically stated in the **Scope of Work** that the Employer is performing the detail design and that the Employer will provide the sag and tension table of values. The cost of preparing the sag and tension charts shall be included in the bid price for the conductor, or in the case where the conductor is free-issued, the cost shall be included in the installation price. For conductor supplied by the Contractor, the Contractor shall be responsible to provide all the technical data for the conductor to calculate the sag and tensions.

8.7.8.7 The appropriate conductor temperature to be used for sagging shall be determined by means of a Celsius thermometer inserted in the end of a suitable length of conductor or earth conductor from

which a 150 mm length has been removed from the centre strand, or other accepted method. The wire with the thermometer inserted shall be hung at cross-arm level for at least two hours before the temperature is read.

8.7.8.8 The length of a section of phase and earth conductors to be regulated at any one time shall be limited to that length that will assure attainment of correct sag based upon terrain and obstructions.

8.7.8.9 Where there are a large number of suspension towers between strain towers, regulating of phase and earth conductors shall be done at intervals of 3 to 5 spans. In hilly terrain the conductors may require to be temporarily anchored one span away from the spans being regulated. The sag spans chosen shall be near each end of the section pulled for single conductor lengths, and near each end and at the middle for double conductor lengths. In addition, the sags shall be checked in all spans over 500 metres. In unusual situations, the Employer's Site Representative may require additional checks.

8.7.8.10 The Contractor shall provide, and maintain in good condition, suitable dynamometers, sighting rods/ scopes, sag boards or other accepted apparatus for the proper checking of the work. Dynamometers shall read in newtons and shall be tested and recalibrated at regular intervals. The Contractor shall keep dynamometer calibration certificates at the site office.

8.7.8.11 The Contractor shall notify the Employer's Site Representative at least twenty-four hours prior to any planned regulating operation. No regulating shall be done except in his presence, unless otherwise authorised. The Contractor shall furnish labour and equipment, for signalling and climbing purposes as requested by the Employer's Site Representative, to facilitate his inspection of the sag.

8.7.8.12 In pulling up the conductor, caution shall be used to avoid pulling the conductor above sag.

8.7.8.13 The maximum elapsed time from the beginning of the pulling operation to the completion of the regulating operation, shall not exceed seventy-two hours, nor shall the maximum elapsed time between the completion of the regulating operation, and the completion of the clamping operation exceed seventy-two hours. Conductor remaining in the blocks longer than the established limits shall be subject to inspection and, if damaged, replaced. The Contractor shall furnish labour and equipment as requested by the Employer's Site Representative for this purpose, as well as for inspection in the event of sudden windstorms.

8.7.8.14 No minus regulating tolerance will be allowed. A plus regulating tolerance of 0.01 times the theoretical sag, but not exceeding 100 mm will be allowed, provided all conductors in the regulating span assume the same relative position to true sag. Sags of conductors in the same bundle shall not vary more than 30 mm relative to one another. Sag variances between phases shall not be apparent to the naked eye.

8.7.8.15 When finally adjusting the sags of conductors and earth conductors, the sag shall be checked with sighting rods/ scopes or sag boards, or other accepted methods in spans where the levels of the two towers are approximately the same, and the span length is approximately equal to the equivalent span length of the strain section. Upon completion of this regulating operation, as many successive spans as can be observed from the sag board position shall be checked for uniformity of sag.

8.7.8.16 All conductors, except for conductors in sag sections over flat terrain, shall be plumb-marked at each structure for the complete section regulated, before clamping-in or dead-ending of the conductor is begun. Conductors shall be marked with paint crayon or wax pencil - not with metal objects.

8.7.8.17 Insulator strings on three suspension towers adjacent to a new section to be regulated must be clamped to the conductor before temporary anchors are removed and regulating of the new section begins. These insulators shall remain in the plumb position upon completion of regulating of the new section and during plumb-marking.

8.7.8.18 Regulating operations shall be conducted during daylight hours only. Regulating operations shall be suspended at any time, when in the opinion of the Employer's Site Representative, wind or other adverse weather conditions would prevent satisfactory regulating.

8.7.8.19 Records of actual (and not the design) temperatures, sag and tension for each section regulated shall be kept by the Contractor, and a copy supplied to the Employer's Engineer.

8.7.8.20 On completion of regulating of a section of the line, the Contractor shall measure and record all clearances over roads, power lines, communication lines, railways etc. along the route. A copy of these records is to be submitted to the Employer's Engineer. The Employer's Site Representative is to be notified immediately of any discrepancy found between the actual clearance and that shown on the profiles.

8.7.8.21 The Contractor shall submit schedules showing the correct (actual as-strung and regulated) initial and final sags and tensions of the line and earth conductors at various temperatures and span lengths, the former making allowance for such permanent stretch as might take place in service.

8.7.8.22 All measurements of length for the purpose of payment shall be to the nearest metre and shall be made after erection along the centre line of the transmission line without allowance for sag.

8.7.9 Clamping of conductors

8.7.9.1 The conductors and earth conductors shall be clamped-in by the Contractor after the Employer's Site Representative has accepted the regulating operation as being in full compliance with the specifications and stringing data. Where offsets are required, the conductors shall be accurately adjusted in accordance with the offset clamping information developed by the Contractor.

8.7.9.2 All conductors in a sag section shall normally be clamped-in, beginning at the second structure from the forward end of the pull, and shall progress structure by structure, until the conductors at all structures are clamped-in.

8.7.9.3 The Contractor shall exercise extreme care in moving the phase and earth conductor from the stringing blocks to the suspension clamps.

8.7.9.4 Where armour rods or conductor clamps incorporating armour rods are called for, they shall be installed in strict accordance with the Manufacturer's recommendations. Armour rods shall be centred in each suspension clamp in such a manner that the clamp is not more than 50 mm from the centre of the rods. Variations between the ends of the individual rods shall not exceed 12 mm. Aluminium rods shall be handled with the same care as the conductor.

8.7.9.5 Properly calibrated torque wrenches shall be used to tighten suspension clamp and dead-end bolts to the Manufacturer's specified torque values. U-bolts shall be drawn up evenly to torque values. Bolts shall not be tightened excessively. Proof of calibration must be submitted to the Employer's Site Representative.

8.7.9.6 All conductor support assemblies shall be installed such that the insulator string will hang in a vertical plane through points of insulator string attachment to structure, with the structure properly aligned.

8.7.10 Vibration dampers

8.7.10.1 Where vibration dampers are specified, these shall be installed at each suspension and strain point.

8.7.10.2 The number of dampers to be installed per span shall be as may be specified, or as recommended by the Manufacturer. The spacing from the mouth of the strain clamp or the centre of the suspension clamp shall be in accordance with the Manufacturer's recommendations.

8.7.10.3 If the use of armour rods makes it impossible to meet this spacing, the first damper shall be positioned at the end of the armour rods, and any additional dampers shall then be spaced from the first damper. Dampers shall be located within 25 mm of their correct position.

8.7.10.4 Vibration dampers shall be installed when clamping the conductor, but only after the conductor has been securely fastened in the conductor support assembly.

8.7.10.5 Stockbridge pattern vibration dampers shall be installed so that they hang directly under the conductor.

8.7.10.6 The installation of vibration dampers shall be in accordance with the Manufacturer's recommendations.

8.7.11 Multi-conductor spacers

8.7.11.1 On lines employing more than one conductor per phase, spacers, shall be installed to separate the individual conductors of each phase.

8.7.11.2 Conductor spacers shall be installed immediately after clamping the conductors, but in no instance shall conductors be allowed to remain without spacers installed for longer than seventy-two hours after clamping.

8.7.11.3 Notwithstanding the allowed times between stringing, regulating, clamping and fitting of vibration dampers and spacers, the overall time for these operations shall not exceed six days (144 hours).

8.7.11.4 Conductor spacers shall be installed within 1000 mm of the positions as per Specifications or Manufacturer’s recommendation.

8.7.11.5 Trolley carts used by the Contractor to move his men along the conductor shall be furnished with neoprene or rubber lined wheels to support the carts on the conductors. The carts shall be equipped with an odometer, which shall run on one sub-conductor and indicate distances in metres. The odometer shall be set in such a manner, as to give the distance from the suspension clamp to all cart positions along the span on the centre phase from which all the hardware on the three phases will be aligned perpendicular to the centre line of each span.

8.7.12 Jumpers

8.7.12.1 The jumpers shall be formed to provide the maximum amount of clearance from earthed hardware, and tower steelwork. Their positioning shall comply with the clearances stated under the specified displacements.

8.7.12.2 The Contractor shall supply labour and equipment to assist the Employer’s Site Representative in measuring clearances from jumpers to earthed hardware if requested.

8.7.12.3 Jumpers not meeting the required clearances shall be removed and replaced.

8.7.13 Objects Affecting Airspace

8.7.13.1 Any communications structure, building or other structure, whether temporary or permanent, which has the potential to endanger aviation in navigable airspace, or has the potential to interfere with the operation of navigation or surveillance systems or Instrument Landing Systems, including meteorological systems for aeronautical purposes, is considered an OBSTACLE and shall be submitted to the Commissioner for Civil Aviation for evaluation (refer SA-CAR Part 139.01.33)

8.7.13.2 The Commissioner requires the proposed route of the power line, the co-ordinates (latitude and longitude in degree, minute, seconds and tenth of seconds format) of deviation points in the line, the maximum height of the structures above ground level and the name of the power line circuit. The Commissioner will evaluate the route and require those sections of the line (if any), which is considered a danger to aviation to be marked or rerouted.

8.7.13.3 The spacing between the spheres and between the spheres and the supporting towers shall not exceed 30m. On lines with multiple conductors, the spheres shall be fitted to the highest conductor, which is the shield or ground wire.

8.7.13.4 Where power lines cross a river or valley, the co-ordinates (latitude and longitude in degree, minute, seconds and tenth of seconds format) and the height of the line above the valley or river, shall be communicated to the Commissioner for publication in the appropriate media.

8.7.13.5 The Commissioner may require that supporting towers be marked and lighted. Lights (Night marking) to be used shall consist of a pair of steady burning approved red aeronautical obstruction lights of at least 32 candela each at the highest practical point of the structure. This may be substituted by a medium intensity Type B flashing red light (20 – 60 flashes per minute), of 2000 candela (±25 %) intensity in accordance with ICAO Annex 14 table 6-3. Lights shall be visible through any azimuth of 360 degree and no light shall be spaced more than 30m apart, on the horizontal plane of any structure.

8.7.13.6 Specification on the lighting and painting of structures can be found in ICAO Annex 14 chapter 6 and the specifics in Annex 14 APPENDIX 1. COLOURS FOR AERONAUTICAL GROUND LIGHTS, MARKINGS, SIGNS AND PANELS.

8.8 On-site tests

8.8.1 Line insulation, voltage and conductivity

8.8.1.1 Insulation tests shall be carried out after erection. If required by the Employer's Engineer, voltage and conductivity tests shall be carried out.

8.8.2 Tower footing resistance measurement

8.8.2.1 The footing resistance of each tower shall be measured prior to the erection of earth conductors. This measurement shall be taken both with and without the earthing system connected.

8.8.3 Measurements and clearance checks

8.8.3.1 The Contractor shall carry out such measurements as may be required or requested by the Employer's Engineer to prove that statutory or specified clearance requirements are complied with.

8.8.3.2 The Contractor shall ensure that all instruments required for this purpose are available on site.