132kV Steel Pole Transmission Lines

Technical Specification for NeSTS 132 kV Double Circuit

Issue 3

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REVISION HISTORY

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MDL	ST, MH, JS		1	22/8/2018	First draft for comment
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Foreword

This Technical Specification is published by Scottish and Southern Energy Networks (SSEN). It sets out the functional requirements and design bases for the new suite of 132kV double circuit, steel, monopole supports.

The intention is that the NeSTS 132kV DC support series will be suitable for application anywhere within Great Britain. The limits of application stated herein are intended to be informative rather than definitive.

This Technical Specification has been prepared to ensure that overhead lines constructed with NeSTS 132kV steel pole supports are compliant with the requirements of the Electricity Safety Quality & Continuity Regulations 2002 (as amended), BS EN 50341-1 and BS EN 50341-2-9.

The analysis on which this Specification is based was undertaken using Power Line Systems Inc 'PLS Pole' software Version 16.51.

1. Scope

This Specification is applicable to new overhead lines constructed with NeSTS 132kV Double Circuit (DC) steel monopole supports.

The extent of the application of BS EN 50341-1 (subsequently referred to as Part 1) in the United Kingdom, is defined in BS EN 50341-2-9 (subsequently referred to as Part 2-9). Where it has been considered appropriate, reference has been made to ENA TS 43-125:2017. The structural design of steel pole sections and crossarm sections has relied upon ASCE 48-11, because design to Eurocodes is not provided by PLS Pole.

Reference should be made to Part 1, Part 2-9, and the Project Specification and where appropriate to ENA TS 43-125, for details of design, manufacture, installation and testing of all other components for the OHL, including the fabrication and installation of the supports.

Support types and extensions have been analysed for compliance with Part 1 and Part 2-9, based on a defined set of generic loading conditions, as set out in the main body of text and design load schedules in Annex B. The suitability of support types and extensions in other site specific loading conditions may be determined by use of NeSTS PLS Pole models and site specific loading data.

The details contained within this specification are presented for use in the preliminary design of overhead lines. All applications of this specification shall be corroborated by appropriate project specific design studies.

2. Normative references

The following referenced documents, in whole or part, are indispensable for the application of this Specification. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.1. Standards publications

BS EN 1992 and NNAs to BS EN 1992
Design of concrete structures

BS EN 1993 and NNAs to BS EN 1993
Design of steel structures

BS EN 1997 and NNAs to BS EN 1997
Geotechnical design

BS EN 10025
Hot rolled products of structural steels

BS EN 50341-1:2012
Overhead electrical lines exceeding AC 1 kV.
General requirements. Common specifications

BS EN 50341-2-9:2017
Overhead electrical lines exceeding AC 1 kV.
National Normative Aspects (NNA) for Great Britain and Northern Ireland

ASCE 48-11: 2012
Design of Steel Transmission Pole Structures

2.2. Other publications

ENA TS 43-125: Issue 2:2017
Design guide and technical specification for overhead lines above 45kV[1]

Electricity Safety, Quality and Continuity Regulations 2002 (and Amendments)

National Grid Company Linesman's Manual M1,
132 kV, 275 kV and 400 kV Overhead lines, ('Dead Line' Working)[2]

[1] The foreword to ENA TS 43-125 Issue 2 implies that it applies to lattice steel supports in particular, and not to pole supports, however, useful guidance is given for overhead lines in general, and to supports for double circuit configurations. Reference has been made to ENA TS 43-125 for certain aspects of the design.

3. Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1. Deterministic design basis

Consideration of the effects of fixed sets of loadings and weather conditions on the overhead line to ensure that the stress in each support component is limited to be within the yield stress or ultimate tensile strength by a factor described as the factor of safety.

The Deterministic design basis has not been used in the development of the NeSTS 132kV DC supports.

3.2. Probabilistic design basis

Consideration of the effects of random variability of loadings and weather conditions on the overhead line to ensure that risk of failure of each support component is acceptably low but using and assumption of a small probability of failure instead of using a factor of safety.

3.3. Partial load factor

Factor dependent on the selected reliability level, used to modify the calculated loads, taking into account the possibility of unfavourable deviations from the characteristic values of the loads, inaccurate modelling and uncertainties in the effects of the loads. [BS EN 50341-1 modified]

3.4. Partial strength factor

Factor used to modify the mechanical strength of a component covering unfavourable deviations from the characteristic values of material properties, inaccuracies in applied conversion factors and uncertainties in geometric properties and the structural resistance model. [BS EN 50341-1 modified. Partial load factor on dead loads for ice loaded load conditions set to 1.0, refer to Table 10.]

3.5. Reliability level

Classification denoting the selected values for wind and ice actions corresponding to a theoretical time-period for return of those climatic actions.

[Reliability levels I, II and III correspond to returns periods 50, 150, and 500 years respectively. Lesser return periods and hence reliability are adopted for some temporary loading conditions and temporary construction.]

4. The Electricity Safety, Quality & Continuity Regulations 2002

Overhead lines constructed using steel monopole supports in accordance with this Specification shall comply with the Electricity Safety, Quality & Continuity Regulations 2002, with either one or both circuits erected.

5. Historical background

5.1. General

The NeSTS 132kV suite of supports has been developed as part of the Network Innovation Competition (NIC) project code SSEN003, to provide a steel pole solution to support of 132 kV overhead lines.

5.2. Design basis

Historically, lattice steel support designs in the United Kingdom have been based on either deterministic design principles or more recently probabilistic design principles, however, the NeSTS 132kV designs are based only on probabilistic design principles. Probabilistic design principles correspond to Approach 1 in both Part 1 and Part 2-9 of BS EN 50341.

6. Conductor system

6.1. Phase conductor and earthwire

The NeSTS 132kV design of supports permits the use of a range of single or twin-conductor bundle arrangements. For the purposes of design development, the conductor system detailed in Table 1 has been used.

Table 1 - Conductor system used for development of NeSTS 132kV supports

Design reference	Phase conductor	Earthwire
NeSTS 132kV DC	1 x 821-AL5 (Araucaria AAAC) to BS EN 50182, round wire	1 x 821-AL5 (Araucaria AAAC) to BS EN 50182, round wire for Loading assessment OR 1 x 109/209 2c AACSR/ACS (23.8m diameter), round wire for clearance checks

For the reassessment of the applied loadings, a conductor system equivalent to:
1 x 821-AL5 (Araucaria AAAC) phase conductor and 821-AL5 (Araucaria AAAC) earthwire has been adopted.

Where alternative conductor systems and span criteria etc., are used, the users of this Specification are responsible for ensuring that electrical clearances are maintained in relation to the site-specific meteorological conditions and line geometry.

The use of suitable optical (OPGW) earthwires are acceptable.

6.2. Ultimate limit state sagging basis

The limit state sagging basis for the conductor system adopted for the assessment of the applied loadings is given in Table 2.

Table 2 - Ultimate limit state sagging basis

Conductor	Everyday tension		Maximum Erection Tension		Creep compensation (°C)
	Tension (kN)	Temperature (°C)	Tension (kN)	Temperature (°C)	
Araucaria AAAC	40	5	50	-20	20
Notes Conductor tensions under maximum working conditions shall not exceed the rated strength divided by partial materials factor (strength factor) = 1.25.					

6.3. Conductor fittings

For details of the design, manufacture, installation and testing of the appropriate conductor's fittings for use with the conductor systems defined in Clause 6.1, reference should be made to the Project Specification.

Conductor fittings shall meet the requirements of BS EN 61284 and will only be type registered for use on conductor designs on which they have been tested.

6.4. Partial strength factors for conductor system

To achieve the objectives of strength coordination as discussed in clause 11.12, the following partial strength factors are recommended.

Component	Partial strength factor
Conductor	1.25
Insulators	1.6
Fittings	1.6

7. Internal and external clearances

7.1. General

Internal electrical clearances both within the span and at the support are based on the Part 1, Approach 1 requirements. Four distinct clearance checks are required, each under specific climatic conditions. Recommendations regarding the clearances to be used under these conditions have been taken from ENA TS 43-125, and reproduced in Table 3 for ease of reference.

Table 3 – Minimum electrical clearances

Nominal voltage	Loading case	Minimum clearance (m)			
		Within the span		At the support	
		cd - cd	cd – e/w	ph – ph	ph - ep
132 kV	Still air	1.35	1.21	1.35	1.22
	3-yr return wind	0.84	0.75	0.84	0.76
	50-yr return wind	0.41	0.28	0.41	0.28
	3-yr return ice	1.35	1.21	1.35	1.22
Legend: cd = conductor, e/w = earthwire, ph – ph = between phases or circuits, ph – ew = between phase conductor and earthed parts.					

7.2. At-Support Internal clearances

All Suspension and Tension Supports respectively have a consistent crossarm geometry and separation.

In addition to the still air clearances specified in Table 3 an additional 1.0 m of horizontal clearance to the transverse face of the tube is required to allow climbing access with both circuits live.

Due to the diverse climatic and profile conditions, that the NeSTS supports may be deployed in, there is no practical generic approach to providing wire clearances and therefore wire clearance checks must be made by the user of this Specification.

By way of guidance for the user:

For suspension supports; insulator swing angles of 0°, 48° and 71° for Still air, 3-yr and 50-yr wind respectively should meet the required clearance with the conductor system identified in table 2. As an example, the following parameters result in acceptable insulator swing angles for a maximum fallaway angle of 20°.

Table 4 - Example parameters for suspension support at-support internal clearances

Condition	Unit	Value
Altitude	m	500
Height of conductor above ground (ave)	m	25
Terrain category		II
Fundamental Velocity from fig 1	m/s	28.5
Area of insulator	m²	0.195
Mass of insulator	kg	44.25
Mass of counterbalance wt (fixed at end of ins)	kg	0
Weight Span	m	221
Wind Span	m	315
Calculated 3 year Swing	degrees	47.9
Calculated 50 Year Swing	degrees	63

To reduce insulator swing angles the use of set weights, and glass or porcelain sets may be possible subject to checks on support loading.

The determination of the conductor or insulator set swing angles was based on the recommendations given in ENA TS 43-125, Pt 1, Annex 3.D.

Tension supports have been checked up to 60° line deviation but as with the suspension supports there is no Generic Condition that suits all cases.

The use of pilot sets, jumper weights and conductor stiffeners to achieve the specified at-support clearances is acceptable. Composite pilot post insulators have been assumed for the outside angle of larger deviation angles above 30°, it is not expected that such devices would be necessary for the inside angle. Departure angles of +10° uplift & -30° fallaway have been considered as the maximum permissible extents.

7.3. External clearances

For details of the external in-span clearances to the ground or other obstacles reference should be made to SSEN document PR-PS-340, Application of Clearances to Overhead Lines at LV to 400kV.

7.4. Downleads

The down-lead clearances quoted in Table 5 are based on the Part 1 ‘Empirical Approach’.

Table 5 - Minimum down-lead clearances within span

Nominal voltage	Loading case	Minimum clearance within span (cd-cd)(m)
132 kV	Still air	2.5 [1]
	3-year return wind speed	1.5 [2]

Notes
cd-cd – spacing between conductors
[1] At maximum continuous conductor temperature
[2] The minimum 3-year return period wind speed conductor to conductor clearance should be achieved with the conductors of one phase subjected to the 3-year return period gust wind speed, while the conductors of the adjacent phase are subjected to the 3-year return period mean hourly wind speed.

7.5. Earthwire shield angle

The earthwire shield angle for NeSTS 132kV DC supports is 45 degrees from the vertical in still air. The shield angle at the support drives the vertical spacing for the earthwire. The shield angle should also be maintained mid span by selecting a suitable earthwire.

7.6. In-span Internal clearances and phase to phase separation

Phase-to-phase separation (Dpp) determines the reliability of the overhead line during switching overvoltages and is based on the minimum value of Dpp that will be maintained under the environmental conditions defined in BS EN 50341-2-9:2017, namely, high wind, combined wind and ice, and heavy ice.

For phase-to-phase in-span clearances, the adopted value of gap factor Kg is 1.35 [NG TS 2.04]. The minimum electrical clearances have been calculated in accordance with IEC 60071-1 and 60071-2.

In-span internal clearances have been driven by the At-support geometry. No specific allowances or mitigations for the effects of conductor gallop or ice drop have been made. Details of any specific measures will be detailed in the Project Specification.

The designer should consider in-span internal clearances particularly when long spans are being considered.

8. Insulators and insulator sets

8.1. General

For details of phase conductor and earthwire attachment points, reference should be made to general arrangement drawings.

8.2. Suspension insulator sets

Suspension sets will meet the requirements of NG TS 3.04.36 and they will be rated to meet the required loading.

The insulator attachment point is designed to accept an 68/5831 swivel with a minimum failing load of 125kN (note that the S4 support maximum vertical design loads marginally exceed this rating)

Details of whether the insulators are to be of Glass, Porcelain or Composite type will be defined in the project specification.

The nominal length of the insulator set assumed for the design studies for single Araucaria is 2063 mm. For wire clearance purposes composite insulator set weights have been used, whereas glass has been used for loading assessments to represent the worst case in either analysis.

8.3. Tension insulator sets

Tension sets will meet the requirements of NG TS 3.04.36 and be rated to meet the required loading.

Details of whether the insulators are to be of Glass, Porcelain or Composite type will be defined in the project specification.

The insulator set attachment is with a swivel, reference 68-8115, with a minimum failing load of 400kN.

The nominal length of the insulator set assumed for the design studies for single Araucaria is 3021 mm.

8.4. Pilot post insulator sets

The need for pilot post insulators on tension support crossarm ends should be confirmed by wire clearance studies. For guidance, they are anticipated to be required on the outside angle of supports exceeding 30° deviation angle. Post insulators may also be required on supports at sites with extreme departure angles.

Pilot posts will be of composite type and will meet the requirements of NG TS 3.04.36.

The nominal lengths of insulators assumed for the design studies for single Araucaria is 1650mm. The minimum Maximum Design Cantilever Load (MDCL) for the insulator will be 7kN.

8.5. Low duty tension insulator sets

Low duty tension sets will meet the requirements of NG TS 3.04.36 and be rated to meet the required loading.

Details of whether the insulators are to be of Glass, Porcelain or Composite type will be defined in the project specification.

8.6. Earthwire sets

The following OPGW drawings represent the preferred arrangement of attachment of the earth bonds.

- 90SS971-68-005 OPGW suspension set
- 90SS971-68-008 OPGW tension set

9. Supports

9.1. General

A range of steel pole supports has been designed to suit a wide range of climatic loading conditions and angles of deviation. There are four suspension support, strength classes (SD1, SD2, SD3, and SD4) and five tension support strength classes (TD1, TD2, TD3, TD4, TD5).

9.2. Types and uses

The range of standard support types available is shown in Table 6, together with their respective angles of deviation and or angles of entry. Each of these support types has been designed so that the support heights may be altered by the extensions or reductions defined in clause 9.3 of this Specification.

Table 6 – Support Suite – Angles of deviation

Code	Description	Deviation (°)
SD1 – SD4	Suspension	0-2
TD1 – TD5	Tension	0 – 60°

All tension supports may be used in in-line positions where it is necessary to arrange for sectioning and tensioning of the phase conductors and earthwire in a straight run of OHL.

All tension support crossarms are able to resist uplift loading. The uplift capacity of the connections indicated by the general arrangement drawings (comprising 6M36 Grade 8.8 bolts, 20x700mm vang plates) is greater than 75 kN.

9.3. Extensions

Details of the extensions and reductions available to the standard types of support are given in Table 7.

An extension to the standard height support is designated by the letter 'E' followed by the height of the extension in metres. A reduction to the standard height is designated by the letter 'M' followed by the height of the reduction in metres.

Table 7 – Support Suite – Range of extensions

Code	Range of normal extensions and reductions to standard height
SD1 – SD4	M6 – E12 (in 2.0m increments)
TD1 – TD6	M6 – E12 (in 2.0m increments)

9.4. Spigot base connections

The connections between a steel pole and its foundation incorporates a truncated reinforced concrete cone. These cones are sized to achieve a minimum insertion into the bottom section of each steel pole of 1.5 x diameter, and they are formed using permanent steel shuttering. The permanent shuttering is extended above the top of concrete level by 400 mm to disperse stress concentration at the concrete/steel tube interface. The truncated concrete cone and formwork is referred to in this Specification as a spigot[3].

[3] Other specifications and design guides refer to 'spigots' by other terms including immured foundations, dowel foundations and foundation pins.

The initial verticality of the axis of each spigot is critical to the overall verticality of the support. Depending on the type of support and the proposed angle of deviation, there may be a site-specific requirement to set at a rake the axis of the spigot during construction, to achieve optimised verticality of the support in everyday conditions, and to suit site-specific construction sequencing.

Spigots are constructed with a diameter and a taper to match that of the bottom of the pole, and at a level that results in the bottom of the pole resting at nominally 500 mm above ground level.

9.5. Base plate with holding down bolts

'Base plate with holding down bolts' connections can be used to secure steel poles to concrete foundations instead of the spigot connections referred to in clause 9.4. These connections, where used, are to be designed in accordance with BS EN 50341-1, Section 7.4.

The base plate and the holding-down bolts shall be designed to transmit all moment and force combinations applied by the support to the foundation.

The holding-down bolt / base flange connection detail is to be designed to achieve good drainage and ventilation at the base of the poles. A clear gap between the foundation and the flange plate is to be maintained for this purpose and correspondingly, holding-down bolts are to be designed to transfer both axial loads and the shear load across the clear gap.

9.6. Ancillary support fittings

9.6.1 Access Facilities

Two access ladders are provided to each support located on plan approximately mid-angle between the transverse axis of the support and the longitudinal axis of the support, but close enough to the crossarms to allow linesmen to safely step from the ladder onto the crossarms. The ladders comprise a central rail with alternate step bolts, and they extend from a level 3.0 m above ground level to the top of the pole. Each ladder is split into sections and secured to the pole by bolted cleats. Ladders are not continuous across slip-joints.

Three access rings are provided at each crossarm level, one below the crossarm, one a nominal step height above the crossarm and one above the stay attachment level. The access rings allow access from one ladder to the other at each crossarm level, and they facilitate access during construction and maintenance activities. Additional access rings and are provided at top of earthwire tube and between ground and bottom crossarm level.

The top surface of all crossarms shall have a painted anti-slip finish. The anti-slip finish is required to enhance safety when the support is accessed in wet conditions. Paint that is loaded with Grit 60 – Grit 80 sand has been found to provide a satisfactory surface finish.

9.6.2 Anti-climbing devices

An assessment of the risk of climbing has been undertaken with reference to ENA TS 43-90. It is evident that the smooth, near vertical sides of the bottom sections of poles deters climbing and so no anti-climbing devices are required for typical sites. However, at some sites there may be a requirement for anti-climbing devices, and to cater for this eventuality, two welded tabs have been specified on all supports, at circa 3.0 m above ground level, for the attachment of a semi-circular lockable anti climbing device.

9.6.3 Safety signs and identification plates

Provisions have been made for attachment of safety signs and identification plates to the supports in accordance with the requirements of ENA TS 43-90.

9.6.4 Livestock guards

The smooth, near vertical sides of the bottom sections of poles is not considered hazardous to livestock; no livestock guards are detailed for standard installations.

9.6.5 Earthwire bonding

To facilitate the attachment of flexible earthwire bonds to the support, a cleat with a 17.5 mm hole is provided on each pole adjacent to the earthwire attachment points.

9.6.6 Earthing of supports

To facilitate connection of earth electrodes to the pole body, welded cleats with 17.5 mm diameter holes have been provided close to ground level. This provision is to be provided in the bottom section of pole at each site.

In addition to direct earthing of steel poles, reinforcement cages in foundations shall be earthed.

9.7. Design Life

The NeSTS supports are to be designed and constructed to have a minimum design life of 80 years. The supports will require limited maintenance; the period to first maintenance is to exceed 20 years.

10. Design basis, actions and reliability

10.1. General

For each support, strength class notional values have been adopted for reliability, span criteria, elevations and basic meteorological parameters, in order to achieve a range of support strengths that are suitable for the United Kingdom and suitable for typical spans and angles of deviation.

Design loads also incorporate ‘construction and maintenance’ load cases and security loads cases, such that all of the standard load cases listed in Part 2-9 have been considered in the design of the supports.

Details of the design loads there were adopted for the design of each support strength class are given in Annex B, Design Load Schedules. The loads stated are an indication of the upper bound load limits that the supports can reliably withstand.

Two circuit configurations have been considered in the design of the NeSTS 132kV DC supports: double circuit and single circuit. Reference should be made to design load schedules listed in clause 10.1 for details of the specific generic climatic loadings that were adopted for the design of individual support types.

10.2. Reliability levels and partial load factors

The reliability levels and associated partial load factors adopted for the generic support loadings are shown in Table 8.

- For suspension supports designed for use in open country reliability level 2 should be adopted.
- For suspension supports constructed in areas adjacent to habitation, or at critical crossings, i.e. critical suspension supports, reliability level 3 should be adopted, and
- For tension and terminal supports, reliability level 3 should be adopted.

Table 8 - Reliability levels and partial load factors

Action (load)	Application	Partial load factor	
Variable actions			
Climatic loads		**RL 2**	**RL 3**
(1a) High wind	γ_v on wind speed	1.1	1.2
(2a) Heavy ice	γ_v on ice thickness r_o	1.1	1.2
(3a) Combined wind and ice	γ_v on ice thickness r_w, and wind speed [1]	1.1	1.2
Safety loads (construction and maintenance loads)			
Active conductor tension	γ_L	2.0	
Landed conductor tension	γ_L	1.5	
Construction loads [2]	γ_L	1.5	
Permanent actions			
Self-weight [3]	γ_{DL}	0.9 or 1.1	
Self-weight for calculation of conductor tensions	γ_{DL}	1.0	
Accidental actions – security loads			
Conductor tensions [4]		1.0	
Climatic loading [5]	γ_v on ice thickness r_w, and wind speed [1]	0.75	0.75

Notes
[1] Factor B1 = 0.68 also applied to wind speed for 3a loading
[2] Applied to access platforms, weight of linesmen etc.
[3] Select value which causes most onerous effects
[4] Unbalanced conductor tensions in broken wire conditions

RL = Reliability level as defined in Part 2-9

10.3. Span criteria

The span criteria defined in Table 11 and Table 12, for suspension supports and tension supports respectively, were adopted in the derivation of notional design vector loads.

For the assessment of notional applied support loadings, the notional span criteria adopted for use with 1 x Araucaria AAAC and 1 x Araucaria AAAC earthwire is shown in Table 9. The span criteria are applicable to support types S1-S4 and T1-T5, and for extension ranges M6-E12.

At all sites, the angle of deviation should be taken into account in the selection of the strength class.

10.4. Basic meteorological parameters

The basic meteorological parameters used to generate the notional design loads for each strength class are detailed in Table 11 and Table 12, for the suspension range and the tension range respectively.

Notes to be read in conjunction with Table 11 and Table 12

- Terrain categories are defined in Part 1.
- The number of wires for double circuit configurations is Nc = 7, and for single circuit configurations Nc = 4.
- Conservative assumptions have been made regarding wind direction, factor C.dir has been set to 1.0.
- Orographic effects have not been considered in the derivation of notional design loads for each strength class, correspondingly factor Co has been set to 1.0. Site specific load assessments should take orography into account.

10.5. Climatic loadings

The following standard climatic loading cases have been considered in the assessment of the applied support loadings.

- Case 1a – Extreme wind at 0°C
- Case 2a – Heavy uniform ice accretion on all spans at -10°C, with unit weight of ice 5.0 kN/m³
- Case 3a – Combined wind and ice, uniform glaze ice on all spans at -10°C, with unit weight of ice 9.0 kN/m³

Table 9 - Suspension - span criteria and meteorological parameters

	SD1	SD2	SD3	SD4
Nominal span	300	300	300	300
Wind span	315	315	315	315
Weight span - max	500	500	500	500
Weight span - min	221	221	221	221
Ruling Span - max	300	300	300	300
Ruling Span - min	150	150	150	150
AOD (angle of deviation)	0.6	1.5	1.8	1.2
Altitude	200	400	500	750
Reliability level	1	2	2	3
Conductor	Araucaria	Araucaria	Araucaria	Araucaria
Nr of wires	7&4	7&4	7&4	7&4
Height of support top	Tension E6	Tension E6	Tension E6	Tension E6
Reference height	Tension E6	Tension E6	Tension E6	Tension E6
Terrain category	ii	ii	i	i
Map wind speed, (vb)	25	25.5	26	26.5
Wind direction (Cdir)	1.00	1.00	1.00	1.00
Orograph factor (Co)	1.00	1.00	1.00	1.00
Radial ice without wind	60	65	65	70
Radial ice WITH wind	10	15	15	20

Table 10 - Tension - span criteria and meteorological parameters

	TD1	TD2	TD3	TD4	TD5
Nominal span	300	300	300	300	300
Wind span	315	315	315	315	315
Weight span - max	500	500	500	500	500
Weight span - min	0	0	0	0	0
Ruling Span - max	300	300	300	300	300
Ruling Span - min	150	150	150	150	150
AOD (angle of deviation)	10	22.5	32.8	42.5	58.9
Altitude	200	300	400	500	700
Reliability level	2	2	3	3	3
Conductor	Araucaria	Araucaria	Araucaria	Araucaria	Araucaria
Nr of wires	7&4	7&4	7&4	7&4	7&4
Height of support top	Tension E6	Tension E6	Tension E6	Tension E6	Tension E6
Reference height	Tension E6	Tension E6	Tension E6	Tension E6	Tension E6
Terrain category	ii	ii	ii	i	i
Map wind speed, vb	26	26.5	27	27.5	28.5
Wind direction (Cdir)	1.00	1.00	1.00	1.00	1.00
Orograph factor (Co)	1.00	1.00	1.00	1.00	1.00
Radial ice without wind	65	70	70	70	75
Radial ice WITH wind	15	20	20	20	25

10.6. Construction and maintenance loadings

The following generic construction and maintenance (C&M) loading conditions have been considered in the assessment of the support loadings.

- Case 4a – Suspension supports – 'catch-off' of phase conductors under still air conditions
- Case 4b – Tension supports – conductor erection or lowering, pulling along the line, still air conditions
- Case 4c – Tension supports – conductor erection or lowering, square-rigged, still air conditions
- Case 4d – Tension supports – earthwire erection or lowering, square-rigged, still air conditions

The C&M loading conditions have been based on procedures set out in National Grid Linesman's Manual M1. In addition to conductor and earthwire tensions, allowance has been made for attachment of an access platform and for linesmen access on crossarms supporting active conductors and earthwires; for further details refer to design note 90SS686-DN-016.

In accordance with Part 1, clause 4.9, an allowance of 1.0 kN has been included in the derivation of C&M loading where linesmen may require access. It has been assumed that two linesmen may be working together at the end of a crossarm that is supporting an 'active' conductor.

It has been assumed that an access platform may be attached to the ends of tension support crossarms during C&M activities, on 'active' conductors. A characteristic weight of 5.85 kN has been adopted in the assessment of C&M loading scenarios.

For loadcases 4a – 4c, a load factor of 1.5 has been applied to conductor weights, to landed conductor tensions, to the weights of insulators, platforms, workers and equipment; a factor of 2.0 has been applied to 'active' conductor tensions.

C&M loading scenarios have been considered in the design of the NeSTS supports; however, the users of this Specification must ensure that the derived loadings together with any associated limitations are adequate for their own particular application.

10.7. Accidental actions – security loadings

The following generic security loading cases have been considered in the calculation of notional design loads.

- Case 5a – Suspension supports – two broken wires, conductor or earthwire, in still are at 5°C, with a tension reduction factor (β) of 0.7
- Case 5a1 – tension supports – two broken wires, conductor or earthwire, in still are at 5°C, with a tension reduction factor (β) of 1.0
- Case 5b tension supports - one broken wire, conductor or earthwire, in 3-year return period combined wind and ice conditions at -10 °C.

10.8. Permanent actions

In the calculation of design loads, permanent actions arising from the self-weight of conductors, insulators, and components of the support etc. have been factored using the values stated in Table 11.

A dead load factor of 1.0 has been adopted in the calculation of conductor tensions for all load cases.

Table 11 – load factors on permanent actions

Case	Condition	Partial dead load factor (γ_{DL})		
		Max Wt Span	Min Wt span	Support
1a	High wind	1.1	0.9	1.1 or 0.9
2a	Heavy ice	1.0	1.0	
3a	W&I	1.0	1.0	
4a – 4d	C&M	1.5/2.0 [1]	N/A	
5a and 5a1	Broken wire – still air	1.1	0.9	
5a2	Broken wire – W&I	1.0	1.0	
Notes C&M – Construction and maintenance loading conditions W&I – Combined wind and ice loading [1] 1.5 applied to landed wires, 2.0 applied to active wires				

10.9. Supplementary actions

10.9.1 Insulator set wind areas

The following insulator set wind areas have been considered in the assessment of the support loadings:

Suspension insulator set 0.36 m²

Tension insulator set 0.58 m²

Post insulator (on tension support xarms) 0.36 m²

10.9.2 Insulator set self-weight

The following vertical loading due to the self-weight of the insulator sets have been considered in the assessment of the support loadings:

Suspension insulator set 0.47 kN

Tension insulator set 1.63 kN

Post insulator (on tension support xarms) 0.47 kN

10.9.3 Down-leads

Site-specific loading checks are to be undertaken for terminal supports.

10.9.4 Site specific load checks

For loading conditions or support types and extensions that are outside those considered by this Specification, the users of this Specification are responsible for undertaking site-specific loading checks.

11. Analysis and design of supports

11.1. Partial strength factors

For the analysis of the supports and strength checks, the partial strength factors shown in Table 12 have been adopted.

Table 12 - Partial strength factors for supports

Material/element property	Partial strength factor (γv)
Resistance of crossarm hollow sections	1.10
Resistance of principal pole	1.10
Resistance of net-section at bolt holes	1.25
Resistance of bolts in shear or bearing	1.25
Resistance of bolts in tension	1.25
Resistance of welded connections	1.25

11.2. Wind loading on supports

The wind loading on supports has been assessed in accordance with Part 1, clause 4.4.4, and Part 2-9.

Direct wind loading on poles has been undertaken by calculating wind loads on short sections of pole within PLS Pole.

11.3. Support self-weight

In calculating the self-weight of the supports, the self-weight of the principal components has been taken into account, including the principal pole and splice overlaps, crossarms, and stays; but no allowance has been included for vang-plates, end-plates, attachment plates, climbing rails, bolts etc.

In determining the weight of ice on the supports, the thickness of ice on principal members has been calculated in accordance with Part 2-9, with Kc = 1.0.

11.4. Tension supports - applied load distribution

All tension support crossarms are tapered and they have the same crossarm tip width of 300 mm. For climatic load cases load distribution between front span and back span are 50/50% generally; for security load cases 50/50% except for broken wires, where the distribution is 0/50%; and for C&M load cases, loads that correspond to conductors that are being worked on are applied to a notional point at the ends of crossarms. Torsional effects arising from dissimilar gravity loads across crossarms are not critical to design.

11.5. Design stresses

The design strengths adopted in the design of the supports are stated in Table 13.

Table 13 - Design stresses adopted in the design of the supports

Material	Yield strength (N/mm²)	Ultimate strength (N/mm²
Steel grade S355 (< 16mm)	355	470
Steel grade S355 (< 40mm)	345	470
Steel grade S460 (< 16mm)	460	540
Steel grade S460 (< 40mm)	440	540
Bolts grade Gr 8.8	640	800

Bolts grade Gr 10.5	900	1000

11.6. Member and connection design

Strength checks on tubular members, including principal poles and crossarms have been made in accordance with ASCE 48-11, using PLS Pole software.

The design and location of connections between support elements, between element sections and between supports and foundations, takes into consideration assembly, erection, maintenance and dismantling operations, assuring safe systems of work at all times.

Generic strength checks on crossarm connections and stay connection have been carried out in accordance with BS EN 1993-1-8, Design of steel structures - Design of joints. The principles of the connection designs illustrated by the general arrangement drawings have been verified by calculation and corroborated by full scale testing.

All crossarm to pole connections on suspension supports comprise 12M30 Grade 8.8 bolts and 550x16 vang plates. All crossarm to pole connections on tension supports comprise 12M36 Grade 8.8 bolts and 700x20 vang plates. Refer to general arrangement drawings for full connection details. Design joint capacities are given in Table 14

Table 14 - Pole/crossarm capacities

	Axial (kN)	M.xx (kN.m)	M.zz (kN.m)
Tension supports	4690	392	234
Suspension supports	3257	232	162
Notes M.xx - moment about the longitudinal axis M.zz- moment about the vertical axis Axial - acting along the axis of the crossarm All moment and axial forces are +ve or -ve			

Alternative connection designs are permissible, but they must be justified by calculation and testing. Connections between poles and crossarms are to have sufficient strength to resist all the combinations of moments, shear forces and axial forces that result from application of the design loads.

Connections between crossarms and principal poles, between stays and principal poles and between stays and crossarms are bolted, to facilitate construction and dismantlement.

Slip-joint connections are preferred within the height of principal poles, for aesthetic reasons and for ease of construction. Slip-joints have been designed in accordance with ASCE 48-11. Slip-joints shall have a minimum lap length of 1.5 times the maximum inside diameter across the flats of the outer section (nominal to be dictated by manufacturing tolerances to ensure the minimum).

11.7. Support analysis

The analysis of the specific support types was undertaken using the 'PLS-Pole version 17.50' computer program, developed by Power Line Systems Inc. 'PLS-Pole' three-dimensional finite element models of the supports were analysed using nonlinear elastic techniques.

11.8. Limits on pole tip deflections

Pole tip deflections corresponding to 3-year climatic loading ($\gamma v = 0.75$) and for for 50-year climatic loading ($\gamma v = 1.00$) shall be limited to the values given below. Deflection limits are expressed as a percentage of pole height.

Support type	3-yr deflection limit	50-yr deflection limit
Suspension supports	3%	5%
Tension supports	2%	3%

The rotation of foundations shall not exceed 1 degree. Foundations are to be designed to achieve this limit.

For tension supports in EDT conditions, it is recommended that calculated pole tip deflections should be less than 1% of pole height. At sites where this limit would be exceeded, raking of poles prior to stringing should be considered

The construction of supports and all stringing of operations shall be designed to fully take into account the effects of elastic deflections of the supports.

11.9. Limitations on mass and size of components

The mass and dimensions of sections of individual support elements have been carefully considered in the development of the NeSTS132kV supports, so as to allow for practical, safe and economic; fabrication, transport, assembly, erection, maintenance and dismantlement. The dimensions and weights of components do not exceed the criteria set out below.

Maximum length of component	13.6 m (transport and galvanising constraints)
Maximum width of component	2.8 m (galvanising limit)
Maximum mass	15 tonne (galvanising limit)

11.10. Corrosion protection

The NeSTS 132kV supports are to be designed, manufactured, and constructed to have a minimum design life of 80 years. The supports will require limited maintenance, but the period to first maintenance is to exceed 20 years.

The internal and external surfaces of all components are to be protected by galvanising in satisfaction of ASTM A123/A123M-17 and BS EN 1461:2009 with a minimum required mean coating thickness of zinc of 0.11mm. Further protection is to be provided to external faces to result in an approved duplex system. Alternative corrosion protection systems may be considered; however, all corrosion protection systems must be suited to achievement of the specified overall design life, the specified time to first maintenance, operational requirements and environmental requirements.

The specification and colour of finish coatings are to be approved and they are to consider all of the environmental objectives. The paint coating will be applied at the point of manufacture, therefore preventing the need for painting on site.

11.11. Limitations on use of this document

This Specification does not extend to consideration of

- Interface with existing OHL designs and configurations
- Special crossing arrangements e.g. large watercourses.

11.12. Strength coordination

With reference to Part 1, Annex A, strength coordination has been considered in the development of the NeSTS supports. The partial factors given in Table 8 and Table 12 result in achievement of the strength coordination outlined in Table 15 - Strength coordination.

Table 15 - Strength coordination

	Major Components	Coordination within Major Components *
Lowest strength	Suspension support	Support, foundations, hardware
	Tension support	Support, foundations, hardware
Not having the lowest strength	Terminal support	Support, foundations, hardware
	Conductor system	Conductors, insulators, hardware

11.13. Limitations on uplift loading at tension support sites

If uplifting loading is predicted by line design studies, full uplift checks shall be undertaken.

For each of the design conditions, the net combined vertical action on a crossarm front and back spans shall not exceed 100 kN, which corresponds to the maximum down pull capacity without stays.

The moment arising from the net factored uplift load shall not exceed the vertical moment capacity of the crossarm to pole connection.

The net loading at each slip-joint shall be assessed and the total net uplift imposed by conductors attached above each slip-joint shall not be greater than half of the dead weight of the structure above, unless uplift restraint straps are fitted. Where required, uplift restraint straps shall be designed to resist a force equal to the total design uplift force from all conductors and the earthwire, less half of the deadweight of the support above the slip joint. Jacking bosses may be used to attach uplift restraint straps.

Where fitted, crossarm stays are to be installed with a nominal tension of 5.0 kN, before stringing. For sites where uplift is expected at EDT, either in the front or back spans, or both, the stays shall be re-tensioned after stringing, to the nominal tension.

12. Foundations

12.1. Foundation loads

Applied foundation loads and moments are given in Annex C inclusive of partial load factors. Foundations should be designed for site specific loading to minimise foundation costs, so the data in Annex C is for reference only and corresponds to maximum and minimum heights of each type/strength suite.

12.2. Partial strength factor for foundations

A minimum partial strength factor of 1.35 shall be adopted for design of foundations. Generally, the strength factors that are adopted for the design of foundations shall be in accordance with BS EN 1997 and associated standards.

12.3. Design standards for foundations and spigot connections

Foundations are to be designed in accordance with BS EN 1997-1, Geotechnical Design.

Reinforced concrete components, including spigots, pile-caps, rafts etc. are to be designed in accordance with BS EN 1992-1.

13. Bibliography

Standards publications

BS EN 1990
Eurocode – Basis of structural design

BS EN 1992 and NNAs to BS EN 1992
Design of concrete structures

BS EN 1993 and NNAs to BS EN 1993
Design of steel structures

BS EN 1997 and NNAs to BS EN 1997
Geotechnical design

BS EN 10025
Hot rolled products of structural steels

BS EN 50341-1:2012
Overhead electrical lines exceeding AC 1 kV.
General requirements. Common specifications

BS EN 50341-2-9:2017
Overhead electrical lines exceeding AC 1 kV.
National Normative Aspects (NNA) for Great Britain and Northern Ireland

ASCE 48-11: 2012
Design of Steel Transmission Pole Structures

Other publications

BS EN 60071-2:1997
Insulation co-ordination – Application guide

BS EN 60652:2004
Loading tests on overhead line structures

BS EN 62305-2:2012
Protection against lightning – Risk management

BS EN 61773
Overhead lines – Testing of foundations for structures

Cigre TB 048
Support top geometry

Cigre TB 063
Guide to procedures for estimating the lightning performance of transmission lines.

Cigre TB 151
Guidelines for Insulation Coordination in Live Working

Cigre TB 348
Support Top Geometry and Mid Span Clearances

Cigre Green Book
Overhead lines, Study committee B2, ISBN : #3319317466

ENA TS 43-90
Anti-climbing devices and safety signs for HV lines up to and including 400 kV

ENA TS 43-125 Issue 2:2017
Design guide and technical specification for overhead lines above 45kV

IEC 60826
Overhead transmission lines - Design criteria

NG TGN(E) 026
Current ratings for overhead lines

NG TS 1
Ratings and requirements for plant, equipment and apparatus

NG TS 2.04
Generic design principles for overhead lines

NG TS 3.04.35
Components for Overhead Lines

NG TS 3.04.36
Insulators and Insulator Sets for Overhead Lines

NG TS 3.04.37
Conductors and Conductor Systems for Overhead Lines

NG UL/PL/ETSR/GN
National Grid Safety Rules and Guidance

NG National Grid Company Linesman's Manual M1,
132 kV, 275 kV and 400 kV Overhead lines, ('Dead Line' Working)

NSI 04
Work on or near high voltage overhead lines [NGUK/PM/ETSR/NSI/04/GN Issue 5]

SSEN Operational Safety Rules (2012)

SSEN PR-PS-340
Application of Clearances to Overhead Lines at LV to 400 kV

SSEN PR-PS-580
Approved Procedure for the Fitting and Removal of Additional Earths on 66, 132, 275 & 400kV Overhead Lines

Statutory Instruments No 2665 (UK)
Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR)

ANNEX (A) – General information used for the assessment of probabilistic design loadings for NeSTS development

Introduction
The NeSTS double circuit supports are essentially 12-sided steel mono-poles with tapered rectangular hollow section steel crossarms. Poles are split into tube sections that are connected by slip-joints. Crossarms are connected to poles via projecting steel plates (vangs) and shear bolts.

There are two support top geometries corresponding to suspension supports and tension supports. A number of strength classes for each support top geometry allows steel weight to be optimised for each site.

At each site, the steel pole is connected to the foundation via a steel cased concrete spigot. An alternative feasible connection detail would comprise flange plates with holding down bolts.

Strength Classes
There are four intermediate NeSTS support strength classes (SD1 - SD4) and five tension NeSTS support strength classes (TD1 - TD5). Design load cases correspond to increasingly severe climatic loading for intermediate supports and tension supports. Design load cases for tension supports also consider increasing angles of deviation.

Design Specifications
The NeSTS supports are designed in accordance with BS EN 50341-2-9:2017 with reference to ASCE 48-11 and BS EN 1993 where applicable. Foundations are to be designed in accordance with BS EN 50341-2-9:2017 with reference to BS EN 1992 and BS EN 1997 where applicable.

Conductor System
For the purposes of developing design loadings, it has been assumed that both the conductors and earthwire are 1 x 821-AL5 (Araucaria AAAC) phase conductors to BS EN 50182. The sagging basis is everyday tension (EDT) 40 kN @ 5°C, maximum erection tension (MET) 50 kN @ -20°C, maximum working tension (MWT) 184 kN @ -10°C, and a creep compensation of 20°C.

For single circuit load configurations the number of wires, Nc = 4. For double circuit load configurations Nc = 7.

Insulators
For the purposes of developing design loadings, generic suspension insulators have been assumed length 2.1 m, rated tension capacity 125 kN, weight 0.75 kN, and wind area 0.36 m². Generic tension insulators have length 3.0 m, rated tension capacity 300 kN, weight 1.625 kN, and wind area 0.58 m².

Load cases
The load cases that have been considered in the development of design loading are indicated in Table A.1.

LC group ref	Loadcase description	(S1) Nom	(S2) Max	(S3) Min	(T1) Nom	(T2) Max	(T3) Min	(T4) OutBal
1	1a(1) - High wind (max wt)		X			X		
2	1a(2) - High wind (min wt)			X			X	
3	2a - Heavy Ice		Y			Y		
4	3a(1) - W+I, Max wind, Max weight		Y			Y		
5	3a(2) - W+I, Max wind, Min weight			X			X	
6	4a C&M - Sups 'catch-off'	X						
7	4b C&M - Tenssion - cond lowering, in line				X			
8	4c C&M - Tension - cond lower, square rig				X			
9	4d C&M - Tension - EW lowering				X			
10	5a- 2BRKW, Nom wind, Nom weight	X			X			
11	5b -1BRKW+W&I, Nom wind sp, Nom wt				X			
12	0.0 °C	X			X			
13	-20°C			X			X	
14	Unbalanced spans, 2a heavy ice							Y

Green - Double circuit only, Orange - both double and single circuit.
Table A.1

Span details of the PLS CADD models referred to in Table A.1 (S1-S3 and T1-T4), are given in Table A.2.

Ref	Description	Ref	Wind span	Weight span	Ruling span front	Ruling span back
S1	**Suspension,** nominal spans	Nom	300	300	300	300
S2	**Suspension,** max wind span, max weight span	Max	315	500	300	300
S3	**Suspension,** max wind span, min weight span	Min	315	221	300	300
T1	**Tension,** nominal spans	Nom	300	300	300	300
T2	**Tension,** max wind span, max weight span	Max	315	500	300	300
T3	**Tension,** max wind span, min weight span	Min	315	0	300	300
T4	**Tension,** nominal spans, max ruling span diff	O Bal	300	300	300	150

Table A.2

Design climatic loading parameters

The climatic loading parameters and geometry factors used in the development of design loadings for suspension NeSTS supports are given in Table A.3

	S.D.1	S.D.2	S.D.3	S.D.4
Nominal span	300	300	300	300
Wind span	315	315	315	315
Weight span - max	500	500	500	500
Weight span - min	221	221	221	221
Ruling Span - max	300	300	300	300
Ruling Span - min	150	150	150	150
AOD (angle of deviation)	0.6	1.5	1.8	1.2
Altitude	200	400	500	750
Reliability level	1	2	2	3
Conductor	Araucaria	Araucaria	Araucaria	Araucaria
Nr of wires	4 & 7	4 & 7	4 & 7	4 & 7
Height of support top	Susp E6	Susp E6	Susp E6	Susp E6
Reference height	Susp E6	Susp E6	Susp E6	Susp E6
Terrain category	ii	ii	i	i
Map wind speed, vb	25	25.5	26	26.5
(Orograph factor)	1.00	1.00	1.00	1.00
Radial ice without wing	60	65	65	70
Radial ice WITH wind	10	15	15	20

Table A.3

The climatic loading parameters and geometry factors used in the development of design loadings for suspension NeSTS supports are given in Table A.4

	T.D.1	T.D.2	T.D.3	T.D.4	T.D.5
Nominal span	300	300	300	300	300
Wind span	315	315	315	315	315
Weight span - max	500	500	500	500	500
Weight span - min	0	0	0	0	0
Ruling Span - max	300	300	300	300	300
Ruling Span - min	150	150	150	150	150
AOD (angle of deviation)	10	22.5	32.8	42.5	58.9
Altitude	200	300	400	500	700
Reliability level	2	2	3	3	3
Conductor	Araucaria	Araucaria	Araucaria	Araucaria	Araucaria
Nr of wires	4 & 7	4 & 7	4 & 7	4 & 7	4 & 7
Height of support top	Tension E6	Tension E6	Tension E6	Tension E6	Tension E6
Reference height	Tension E6	Tension E6	Tension E6	Tension E6	Tension E6
Terrain category	ii	ii	ii	i	i
Map wind speed, vb	26	26.5	27	27.5	28.5
(Orograph factor)	1.00	1.00	1.00	1.00	1.00
Radial ice without wing	65	70	70	70	75
Radial ice WITH wind	15	20	20	20	25

Table A.4

ANNEX (B) – Probabilistic design loadings

The following load cases have been considered in the development of the NeSTS 132 kV DC supports.

1a	High wind
1a(3-yr)	3-year high wind
1a(50-yr)	50-year high wind
2a	Heavy Ice
3a	Combined W+I
3a(3-yr)	3-year wind & ice
3a(50-yr)	50-year wind & ice
4a	C&M Susp - Catch-off
4b	C&M Tens - Pull along line
4c	C&M Tens - Square-rigged
4d	C&M Tens - EW square-rigged
5a (5a1)	Two broken wires
5b (5a2)	One broken wire with W+I
5a(SC)	One broken wire (SC)
5b(SC)	One broken wire with W+I (SC)

ANNEX (C) – Sample foundation loads and moments

S.D.1	M6						
Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#193	Still -20°C	-1	-5	-99	78	-7
Min V	#166	Heavy Ice (2a)	0	-7	-363	145	-4
Max M.trans	#140	High Wind (1a)	0	-124	-171	1974	-4
Min M.trans	#153	High Wind (1a)	0	115	-171	-1796	-4
Max M.long	#048	Brk wire (5a)	67	-3	-127	58	1418
Min M.long	#069	Brk wire (5a)	-68	-3	-127	58	-1433

S.D.2							
Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#193	Still -20°C	-1	-11	-112	186	-10
Min V	#166	Heavy Ice (2a)	0	-21	-486	397	-6
Max M.trans	#140	High Wind (1a)	-1	-227	-187	3523	-6
Min M.trans	#153	High Wind (1a)	-1	195	-187	-2962	-6
Max M.long	#048	Brk wire (5a)	67	-7	-143	118	1407
Min M.long	#069	Brk wire (5a)	-69	-7	-143	118	-1428

S.D.3							
Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#193	Still -20°C	-1	-13	-121	223	-13
Min V	#166	Heavy Ice (2a)	-1	-26	-523	488	-8
Max M.trans	#140	High Wind (1a)	-1	-320	-199	4974	-8
Min M.trans	#153	High Wind (1a)	-1	272	-199	-4136	-8
Max M.long	#152	High Wind (1a)	123	-9	-199	161	1567
Min M.long	#146	High Wind (1a)	-123	-9	-199	161	-1567

S.D.1	E12	
Criteria	LC	LC type
Max V	#193	Still -20°C
Min V	#166	Heavy Ice (2a)
Max M.trans	#140	High Wind (1a)
Min M.trans	#153	High Wind (1a)
Max M.long	#048	Brk wire (5a)
Min M.long	#069	Brk wire (5a)

S.D.2	E12	
Criteria	LC	LC type
Max V	#193	Still -20°C
Min V	#166	Heavy Ice (2a)
Max M.trans	#140	High Wind (1a)
Min M.trans	#153	High Wind (1a)
Max M.long	#152	High Wind (1a)
Min M.long	#146	High Wind (1a)

S.D.3	E12	
Criteria	LC	LC type
Max V	#193	Still -20°C
Min V	#166	Heavy Ice (2a)
Max M.trans	#140	High Wind (1a)
Min M.trans	#153	High Wind (1a)
Max M.long	#152	High Wind (1a)
Min M.long	#146	High Wind (1a)

T.D.1 M6

Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#361	Still -20°C	-1	-71	-102	1042	-7
Min V	#334	Heavy Ice (2a)	0	-126	-467	1891	-4
Max M.trans	#308	High Wind (1a)	0	-273	-214	3889	-4
Min M.trans	#510	W&I (3a)	0	135	-218	-2254	-2
Max M.long	#048	Brk wire 5a	79	-42	-170	602	1532
Min M.long	#468	Ice Obal	-181	-111	-341	1649	-2703

T.D.2

Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#366	High Wind (1a)	1	-219	-120	3105	314
Min V	#334	Heavy Ice (2a)	0	-312	-547	4644	-5
Max M.trans	#415	High Wind (1a)	-1	-450	-147	6403	-6
Min M.trans	#510	W&I (3a)	0	265	-275	-4306	-3
Max M.long	#324	High Wind (1a)	196	-22	-236	516	2707
Min M.long	#468	Ice Obal	-194	-260	-386	3867	-2886

T.D.3

Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#375	High Wind (1a)	-1	-77	-148	1580	-7
Min V	#334	Heavy Ice (2a)	-1	-506	-657	7518	-6
Max M.trans	#335	W&I (3a)	0	-735	-437	10763	-4
Min M.trans	#510	W&I (3a)	0	436	-339	-6973	-4
Max M.long	#324	High Wind (1a)	368	-76	-270	1428	5145
Min M.long	#330	High Wind (1a)	-368	-76	-270	1428	-5145

T.D.4

Criteria	LC	LC type	F.long (kN)	F.trans (kN)	F.vert (kN)	M.trans (kN.m)	M.long (kN.m)
Max V	#375	High Wind (1a)	-1	-162	-168	3062	-10
Min V	#335	W&I (3a)	-1	-1019	-727	14830	-7
Max M.trans	#335	W&I (3a)	-1	-1019	-727	14830	-7
Min M.trans	#510	W&I (3a)	0	643	-386	-10143	-5

T.D.1 E12

Criteria	LC	LC type
Max V	#361	Still -20°C
Min V	#334	Heavy Ice (2a)
Max M.trans	#308	High Wind (1a)
Min M.trans	#510	W&I (3a)
Max M.long	#048	Brk wire 5a
Min M.long	#468	Ice Obal

T.D.2 E12

Criteria	LC	LC type
Max V	#375	High Wind (1a)
Min V	#334	Heavy Ice (2a)
Max M.trans	#308	High Wind (1a)
Min M.trans	#510	W&I (3a)
Max M.long	#324	High Wind (1a)
Min M.long	#330	Ice Obal

T.D.3 E12

Criteria	LC	LC type
Max V	#375	High Wind (1a)
Min V	#334	Heavy Ice (2a)
Max M.trans	#335	W&I (3a)
Min M.trans	#510	W&I (3a)
Max M.long	#324	High Wind (1a)
Min M.long	#330	High Wind (1a)

T.D.4 E12

Criteria	LC	LC type
Max V	#375	High Wind (1a)
Min V	#335	W&I (3a)
Max M.trans	#335	W&I (3a)
Min M.trans	#510	W&I (3a)

ANNEX (D) – Design forces and effects of forces for connection design

There are two connection details at the interface of xarms and pole, one for suspension supports and one for tension supports. Both have similar configurations, but plate sizes and bolt details are different. Refer to general arrangement drawings for full details.

The PLS Pole models include CAN elements which allow connection resistance to selected moments and forces to be checked against the moments and forces that arise from the design actions. The CAN elements in the PLS Pole models are located at the pole/crossarm interface and they consider.

- Bending about axis zz corresponding to longitudinal load vectors
- Bending about axis xx, corresponding to vertical load vectors
- And forces acting along the transverse axis

The resistances that are included in the PLS Pole models are as follows

	PLS ref	Units	Suspension	Tension
Mxx.res	M-long	kN.m	+/- 232	+/- 162
Mzz.res	M-vert	kN.m	+/- 391	+/- 234
Fy.res	Trans	kN	+/- 3257	+/- 4690

CAN utilisations are calculated by PLS Pole as

Utilisation = Mxx.app/(Mxx.res * SF) + Mzz.app/(Mzz.res * SF) + Fy.app/(Fy.res * SF)

Mxx.app - applied moment about the xx axis, Mzz.app - applied moment about the zz axis, Fy.app - applied transvers load.
Mxx.res - resistance moment about the xx axis, Mzz.res - resistance moment about the zz axis, Fy.res - resistance to transvers load.
SF - safety factor (0.91)

The Mxx.res for tension supports is set as the maximum Mxx proved by testing. Testing indicated elastic response to a vertical load of 117.7 kN, which corresponds to a CAN resistance moment Mxx.res= 117.8*3.32=391 kN.m. This value is included in the PLS Pole models.

The Mzz.res for tension supports is set as the maximum Mzz proved by testing. The maximum test load was L = 70.4 kN, which corresponds to Mzz.res = 70.4*3.32=234 kN.m.. This value is included in the PLS Pole models, however, the testing did not test to the Mzz limit, and calculations indicate a greater resistance. A greater value of Mzz.res may be justified by further testing, FE modelling or calculation.

Mxx.res and Mzz.res values for suspension supports have derived by factoring down tension support values.

Fy.res values for tension supports and suspension supports have been calculated in accordance with BS EN 1993.

ANNEX (E) – General Arrangement Drawings

NeSTS 132 kV DC – General details

Project	Series	Doc No.	Sheet	Title
90SS902	GA-D	001		Anti-Climbing Device
90SS902	GA-D	002		Pole ID Bracket
90SS902	GA-D	003		Helicopter ID Bracket
90SS902	GA-D	004		Rigging Plates
90SS902	GA-D	005		Typical Access Rings
90SS902	GA-D	006		Bottom Pole Access Ring
90SS902	GA-D	007		Jacking Brackets
90SS902	GA-D	008		Access Ladders
90SS902	GA-D	009		Typical Suspension Crossarm
90SS902	GA-D	010		Suspension Cap Plate
90SS902	GA-D	011		Levelling Brackets
90SS902	GA-D	012		Earthwire Brackets
90SS902	GA-D	013		Detan Crossarm Stays
90SS902	GA-D	014		Tension Cap Plate
90SS902	GA-D	015		Typical Tension Crossarm
90SS902	GA-D	016		Flange Plate Connection TD1 to TD5 Only

NeSTS 132 kV DC – Suspension – General arrangement drawings

Project	Series	Doc No.	Sheet	Title
90SS902	GA-	SD1-P1		Pole Section P1 for SD1 Poles
90SS902	GA-	SD1-P2		Pole Section P2 for SD1 Poles
90SS902	GA-	SD1-P3		Pole Section P3 for SD1 Poles
90SS902	GA-	SD1-P4		Pole Section P4 for SD1 Poles
90SS902	GA-	SD1-P5		Pole Section P5 for SD1 Poles
90SS902	GA-	SD1-P6		Pole Section P6 for SD1 Poles
90SS902	GA-	SD1-P7		Pole Section P7 for SD1 Poles
90SS902	GA-	SD1-P8		Pole Section P8 for SD1 Poles
90SS902	GA-	SD1-P9		Pole Section P9 for SD1 Poles
90SS902	GA-	SD1-P10		Pole Section P10 for SD1 Poles
90SS902	GA-	SD1-P11		Pole Section P11 for SD1 Poles
90SS902	GA-	SD1-P12		Pole Section P12 for SD1 Poles
90SS902	GA-	SD1-P13		Pole Section P13 for SD1 Poles
90SS902	GA-	SD1-P14		Pole Section P14 for SD1 Poles
90SS902	GA-	SD1-P15		Pole Section P15 for SD1 Poles
90SS902	GA-	SD1-P16		Pole Section P16 for SD1 Poles
90SS902	GA-	SD1-P17		Pole Section P17 for SD1 Poles
90SS902	GA-			
90SS902	GA-	SD2-P1		Pole Section P1 for SD2 Poles
90SS902	GA-	SD2-P2		Pole Section P2 for SD2 Poles
90SS902	GA-	SD2-P3		Pole Section P3 for SD2 Poles
90SS902	GA-	SD2-P4		Pole Section P4 for SD2 Poles
90SS902	GA-	SD2-P5		Pole Section P5 for SD2 Poles
90SS902	GA-	SD2-P6		Pole Section P6 for SD2 Poles
90SS902	GA-	SD2-P7		Pole Section P7 for SD2 Poles
90SS902	GA-	SD2-P8		Pole Section P8 for SD2 Poles
90SS902	GA-	SD2-P9		Pole Section P9 for SD2 Poles
90SS902	GA-	SD2-P10		Pole Section P10 for SD2 Poles
90SS902	GA-	SD2-P11		Pole Section P11 for SD2 Poles
90SS902	GA-	SD2-P12		Pole Section P12 for SD2 Poles
90SS902	GA-	SD2-P13		Pole Section P13 for SD2 Poles
90SS902	GA-	SD2-P14		Pole Section P14 for SD2 Poles
90SS902	GA-	SD2-P15		Pole Section P15 for SD2 Poles
90SS902	GA-	SD2-P16		Pole Section P16 for SD2 Poles
90SS902	GA-	SD2-P17		Pole Section P17 for SD2 Poles
90SS902	GA-			
90SS902	GA-	SD3-P1		Pole Section P1 for SD3 Poles
90SS902	GA-	SD3-P2		Pole Section P2 for SD3 Poles
90SS902	GA-	SD3-P3		Pole Section P3 for SD3 Poles
90SS902	GA-	SD3-P4		Pole Section P4 for SD3 Poles
90SS902	GA-	SD3-P5		Pole Section P5 for SD3 Poles
90SS902	GA-	SD3-P6		Pole Section P6 for SD3 Poles
90SS902	GA-	SD3-P7		Pole Section P7 for SD3 Poles
90SS902	GA-	SD3-P8		Pole Section P8 for SD3 Poles
90SS902	GA-	SD3-P9		Pole Section P9 for SD3 Poles
90SS902	GA-	SD3-P10		Pole Section P10 for SD3 Poles
90SS902	GA-	SD3-P11		Pole Section P11 for SD3 Poles
90SS902	GA-	SD3-P12		Pole Section P12 for SD3 Poles
90SS902	GA-	SD3-P13		Pole Section P13 for SD3 Poles
90SS902	GA-	SD3-P14		Pole Section P14 for SD3 Poles
90SS902	GA-	SD3-P15		Pole Section P15 for SD3 Poles

90SS902	GA-	SD3-P16	Pole Section P16 for SD3 Poles
90SS902	GA-	SD3-P17	Pole Section P17 for SD3 Poles
90SS902	GA-		
90SS902	GA-	SD4-P1	Pole Section P1 for SD4 Poles
90SS902	GA-	SD4-P2	Pole Section P2 for SD4 Poles
90SS902	GA-	SD4-P3	Pole Section P3 for SD4 Poles
90SS902	GA-	SD4-P4	Pole Section P4 for SD4 Poles
90SS902	GA-	SD4-P5	Pole Section P5 for SD4 Poles
90SS902	GA-	SD4-P6	Pole Section P6 for SD4 Poles
90SS902	GA-	SD4-P7	Pole Section P7 for SD4 Poles
90SS902	GA-	SD4-P8	Pole Section P8 for SD4 Poles
90SS902	GA-	SD4-P9	Pole Section P9 for SD4 Poles
90SS902	GA-	SD4-P10	Pole Section P10 for SD4 Poles
90SS902	GA-	SD4-P11	Pole Section P11 for SD4 Poles
90SS902	GA-	SD4-P12	Pole Section P12 for SD4 Poles
90SS902	GA-	SD4-P13	Pole Section P13 for SD4 Poles
90SS902	GA-	SD4-P14	Pole Section P14 for SD4 Poles
90SS902	GA-	SD4-P15	Pole Section P15 for SD4 Poles
90SS902	GA-	SD4-P16	Pole Section P16 for SD4 Poles
90SS902	GA-	SD4-P17	Pole Section P17 for SD4 Poles

NeSTS 132 kV DC – Tension – General arrangement drawings

Project	Series	Doc No.	Sheet	Title
90SS902	GA-	TD1-P1		Pole Section P1 for TD1 Poles
90SS902	GA-	TD1-P2		Pole Section P2 for TD1 Poles
90SS902	GA-	TD1-P3		Pole Section P3 for TD1 Poles
90SS902	GA-	TD1-P4		Pole Section P4 for TD1 Poles
90SS902	GA-	TD1-P5		Pole Section P5 for TD1 Poles
90SS902	GA-	TD1-P6		Pole Section P6 for TD1 Poles
90SS902	GA-	TD1-P7		Pole Section P7 for TD1 Poles
90SS902	GA-	TD1-P8		Pole Section P8 for TD1 Poles
90SS902	GA-	TD1-P9		Pole Section P9 for TD1 Poles
90SS902	GA-	TD1-P10		Pole Section P10 for TD1 Poles
90SS902	GA-	TD1-P11		Pole Section P11 for TD1 Poles
90SS902	GA-	TD1-P12		Pole Section P12 for TD1 Poles
90SS902	GA-	TD1-P13		Pole Section P13 for TD1 Poles
90SS902	GA-	TD1-P14		Pole Section P14 for TD1 Poles
90SS902	GA-	TD1-P15		Pole Section P15 for TD1 Poles
90SS902	GA-	TD1-P16		Pole Section P16 for TD1 Poles
90SS902	GA-	TD1-P17		Pole Section P17 for TD1 Poles
90SS902	GA-			
90SS902	GA-	TD2-P1		Pole Section P1 for TD2 Poles
90SS902	GA-	TD2-P2		Pole Section P2 for TD2 Poles
90SS902	GA-	TD2-P3		Pole Section P3 for TD2 Poles
90SS902	GA-	TD2-P4		Pole Section P4 for TD2 Poles
90SS902	GA-	TD2-P5		Pole Section P5 for TD2 Poles
90SS902	GA-	TD2-P6		Pole Section P6 for TD2 Poles
90SS902	GA-	TD2-P7		Pole Section P7 for TD2 Poles
90SS902	GA-	TD2-P8		Pole Section P8 for TD2 Poles
90SS902	GA-	TD2-P9		Pole Section P9 for TD2 Poles
90SS902	GA-	TD2-P10		Pole Section P10 for TD2 Poles
90SS902	GA-	TD2-P11		Pole Section P11 for TD2 Poles
90SS902	GA-	TD2-P12		Pole Section P12 for TD2 Poles
90SS902	GA-	TD2-P13		Pole Section P13 for TD2 Poles
90SS902	GA-	TD2-P14		Pole Section P14 for TD2 Poles
90SS902	GA-	TD2-P15		Pole Section P15 for TD2 Poles
90SS902	GA-	TD2-P16		Pole Section P16 for TD2 Poles
90SS902	GA-	TD2-P17		Pole Section P17 for TD2 Poles
90SS902	GA-			
90SS902	GA-	TD3-P1		Pole Section P1 for TD3 Poles
90SS902	GA-	TD3-P2		Pole Section P2 for TD3 Poles
90SS902	GA-	TD3-P3		Pole Section P3 for TD3 Poles
90SS902	GA-	TD3-P4		Pole Section P4 for TD3 Poles
90SS902	GA-	TD3-P5		Pole Section P5 for TD3 Poles
90SS902	GA-	TD3-P6		Pole Section P6 for TD3 Poles
90SS902	GA-	TD3-P7		Pole Section P7 for TD3 Poles
90SS902	GA-	TD3-P8		Pole Section P8 for TD3 Poles
90SS902	GA-	TD3-P9		Pole Section P9 for TD3 Poles
90SS902	GA-	TD3-P10		Pole Section P10 for TD3 Poles
90SS902	GA-	TD3-P11		Pole Section P11 for TD3 Poles
90SS902	GA-	TD3-P12		Pole Section P12 for TD3 Poles
90SS902	GA-	TD3-P13		Pole Section P13 for TD3 Poles
90SS902	GA-	TD3-P14		Pole Section P14 for TD3 Poles
90SS902	GA-	TD3-P15		Pole Section P15 for TD3 Poles

90SS902	GA-	TD3-P16	Pole Section P16 for TD3 Poles
90SS902	GA-	TD3-P17	Pole Section P17 for TD3 Poles
90SS902	GA-		
90SS902	GA-	TD4-P1	Pole Section P1 for TD4 Poles
90SS902	GA-	TD4-P2	Pole Section P2 for TD4 Poles
90SS902	GA-	TD4-P3	Pole Section P3 for TD4 Poles
90SS902	GA-	TD4-P4	Pole Section P4 for TD4 Poles
90SS902	GA-	TD4-P5	Pole Section P5 for TD4 Poles
90SS902	GA-	TD4-P6	Pole Section P6 for TD4 Poles
90SS902	GA-	TD4-P7	Pole Section P7 for TD4 Poles
90SS902	GA-	TD4-P8	Pole Section P8 for TD4 Poles
90SS902	GA-	TD4-P9	Pole Section P9 for TD4 Poles
90SS902	GA-	TD4-P10	Pole Section P10 for TD4 Poles
90SS902	GA-	TD4-P11	Pole Section P11 for TD4 Poles
90SS902	GA-	TD4-P12	Pole Section P12 for TD4 Poles
90SS902	GA-	TD4-P13	Pole Section P13 for TD4 Poles
90SS902	GA-	TD4-P14	Pole Section P14 for TD4 Poles
90SS902	GA-	TD4-P15	Pole Section P15 for TD4 Poles
90SS902	GA-	TD4-P16	Pole Section P16 for TD4 Poles
90SS902	GA-	TD4-P17	Pole Section P17 for TD4 Poles
90SS902	GA-		
90SS902	GA-	TD5-P1	Pole Section P1 for TD5 Poles
90SS902	GA-	TD5-P2	Pole Section P2 for TD5 Poles
90SS902	GA-	TD5-P3	Pole Section P3 for TD5 Poles
90SS902	GA-	TD5-P4	Pole Section P4 for TD5 Poles
90SS902	GA-	TD5-P5	Pole Section P5 for TD5 Poles
90SS902	GA-	TD5-P6	Pole Section P6 for TD5 Poles
90SS902	GA-	TD5-P7	Pole Section P7 for TD5 Poles
90SS902	GA-	TD5-P8	Pole Section P8 for TD5 Poles
90SS902	GA-	TD5-P9	Pole Section P9 for TD5 Poles
90SS902	GA-	TD5-P10	Pole Section P10 for TD5 Poles
90SS902	GA-	TD5-P11	Pole Section P11 for TD5 Poles
90SS902	GA-	TD5-P12	Pole Section P12 for TD5 Poles
90SS902	GA-	TD5-P13	Pole Section P13 for TD5 Poles
90SS902	GA-	TD5-P14	Pole Section P14 for TD5 Poles
90SS902	GA-	TD5-P15	Pole Section P15 for TD5 Poles
90SS902	GA-	TD5-P16	Pole Section P16 for TD5 Poles
90SS902	GA-	TD5-P17	Pole Section P17 for TD5 Poles

ANNEX (F) – Key Diagrams

NeSTS 132 kV DC – Key diagrams

Project	Series	Doc No.	Sheet	Title
90SS902	KD-	SD1		132kV Suspension Double Circuit Support Strength Class 1 (SD1) Key Diagram
90SS902	KD-	SD2		132kV Suspension Double Circuit Support Strength Class 2 (SD2) Key Diagram
90SS902	KD-	SD3		132kV Suspension Double Circuit Support Strength Class 3 (SD3) Key Diagram
90SS902	KD-	SD4		132kV Suspension Double Circuit Support Strength Class 4 (SD4) Key Diagram
90SS902	KD-	TD1		132kV Tension Double Circuit Support Strength Class 1 (TD1) Key Diagram
90SS902	KD-	TD2		132kV Tension Double Circuit Support Strength Class 2 (TD2) Key Diagram
90SS902	KD-	TD3		132kV Tension Double Circuit Support Strength Class 3 (TD3) Key Diagram
90SS902	KD-	TD4		132kV Tension Double Circuit Support Strength Class 4 (TD4) Key Diagram
90SS902	KD-	TD5		132kV Tension Double Circuit Support Strength Class 5 (TD5) Key Diagram

ANNEX (G) – Manufacturing Tolerances

G.1. Conformance to BS EN 1090

G.1.1. BS EN 1090-1:2009 + A1:2011

Manufacturing shall comply with the requirements of BS EN 1090-1:2009 + A1:2011 except where modified by this annex.

G.1.2. **BS EN 1090-2:2018**

Manufacturing shall comply with EXC2 defined in BS EN 1090-2:2018 except when modified by this annex.

Additional information where applicable, not specified in the relevant NeSTS Preliminary Technical Specification or NeSTS Technical Specification and their associated drawings, an as defined A.1 is as follows:

4.2.1 Factory Acceptance Testing is required prior to shipment unless agreed otherwise in writing by the Client.

6.10 Trial assembly of crossarms to poles is required prior to painting.

8.2.4 Bolts for structural connections, including crossarm to pole connections and flange plate connections shall comply with BS EN 14399. Washers shall comply with BS EN 14399-5.

11.1 Special tolerances are specified in clause 2 of this annex

11.3.2 Functional tolerances shall be Class 1, except as otherwise noted in clause 2 of this annex.

F.1.3 Surface preparation shall be P2

Options, where applicable, and as defined in A.2;

5.2 Traceability for each individual constituent product is required.

6.6.1 The dimensions of holes for bolts shall comply with Table 11.

7.5.6 No special requirements.

7.5.9.1 Transverse butt welds in poles shall not be located within 1.0m of slip-joints.

8.2.1 Bolt assemblies in crossarm to pole connections and in flange plate connections are to include full lock nuts

10.2 Surface preparation shall be P2

G.2. **Tolerances**

G.2.1. General

Tolerances in fabrication and erection shall ensure compliance with clearance, appearance, strength and assembly requirements.

G.2.2. Interchangeability

Sections and components of one structure shall fit and be interchangeable with all other structures of the same type and height.

G.2.3. Slip-joints

At slip-joints, the sum of the lengths of gaps between male and female parts that exceed 3mm shall not exceed 30% of the slip-joint circumference (length of flats). Also, any gap that extends across two adjacent flats, shall not exceed 6mm at any point.

G.2.4. Independence of Tolerances

Tolerances are independent. No individual tolerance can be met through combination of multiple specified, referenced, or implied tolerances.

G.3. Table of Tolerances

The tolerances stated below apply.

Tolerances for NeSTS 132 Double Circuit Supports

	Max tolerance	Min tolerance	Other tolerance
Overall geometry			
Overall length of support (assembled)	+25.0 mm	-25.0 mm	for slip-jointed structures, +150mm per slip-joint
Spacing between crossarms at pole	+25.0 mm	0 mm	
Offset of attachment point (xarm length)	+25.0 mm	0 mm	
Slope of crossarms	+0.5 deg	-0.5 deg	
Vertical alignment of crossarms			0.167 degrees/m
Twist in structure after sleeving			3 degrees
Straightness			2 in 1000
Tubes			
Flat to flat, diameter,	+20.0 mm/m	0 mm	
Length of tube	+25.0 mm	-25.0 mm	
Ovality	+1% diameter	-1% diameter	
Slip-joints			
Minimum length of slip-joint overlap	+10% of design length	0 mm	
Inside diameter of inside piece of fitting pieces	+ 5.0 mm	0 mm	
Outside diameter of fitting piece	0 mm	-2.0 mm	
Base plates (where fitted)			
Plan dimensions	+ 25.0 mm	- 6.0 mm	
Pole eccentricity	+ 5.0 mm	- 5.0 mm	
Spacing between HD bolts	+1.5 mm	-1.5 mm	
Squareness to pole CL	+ 3.0 mm	- 3.0 mm	
Flatness, deviation from flat	+ 5.0 mm	- 5.0 mm	
Other			
Thickness of steel			BS EN 10029, Class C
Length and widths of plates	+ 2.0 mm	- 2.0 mm	
Location of non-mating pieces on a weldment	+ 3.0 mm	- 3.0 mm	
Deviation from flat of flat plates	+ 3.0 mm	- 3.0 mm	
Deviation from flat of mating surfaces	+1.5 mm	-1.5 mm	
Location of a drilled hole in a piece	+ 3.0 mm	- 3.0 mm	
Centres of holes (within group)	+ 1.0 mm	- 1.0 mm	
Centres of holes (between groups)	+ 2.0 mm	- 2.0 mm	
bolt hole diameter (after galvanising)	+ 1.5 mm	0 mm	
Hardware locations relative to top of support	+50.0 mm	-50.0 mm	