

# SECTION-VII B

## HTLS CONDUCTOR

TECHNICAL SPECIFICATIONS

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Revision History

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## TECHNICAL SPECIFICATIONS

### SECTION-VII B

#### HTLS CONDUCTOR

#### 1.0 Description of High Temperature Low Sag (HTLS) Conductor and its Technical Requirements

The offered HTLS Conductor shall be capable of providing the specified ampacity at a continuous operating conductor temperature not exceeding the maximum permissible operating temperature of the offered HTLS Conductor and without exceeding the level of maximum permissible sag as specified in Section-I. The physical and operating performance requirements of the transmission line with HTLS conductor are mentioned below. The Bidder shall indicate technical particulars and details of construction of the proposed conductor in the relevant GTP schedule of BPS. During detailed engineering stage, the contractor shall submit detailed calculation in support of the various parameter quoted by them in the Guaranteed Technical Particulars and the same shall be verified to establish compliance with the specified requirements i.e. Current Carrying Capacity, DC/AC Resistance, Physical dimensional, Sag-Tension etc. In case any changes are required in the design of HTLS conductors to comply with the stipulated requirement of the technical specification during detailed engineering, the same shall be carried out without any extra cost to Employer.

The supplier shall be responsible for satisfactory performance of complete conductor system along with fittings offered by them for continuous operation at the designed maximum temperature (i.e. the steady state conductor surface temperature corresponding to the specified current per conductor/ sub-conductor under ambient conditions specified at 1.4) specified for the HTLS conductor.

#### 1.1 Physical Requirements

Physical dimensions i.e. overall diameter and mass of complete conductor shall be as specified in Section- I. Direction of lay of outer layer shall be right hand.

#### 1.2 Operating performance requirements

1.2.1 The design of HTLS conductor shall be suitable for operation at a steady state conductor temperature experienced for a conductor/ sub-conductor AC current flow as specified in the section- I under the ambient conditions based on ampacity calculations mentioned in clause 1.4.

1.2.2 The HTLS conductor shall be suitable for continuous operation without any deterioration of its electrical, mechanical & metallurgical properties up to the maximum permissible conductor temperature guaranteed by the bidder in the

GTP Schedule. However, the maximum permissible conductor temperature for continuous operation shall not be considered more than 210<sup>0</sup> C.

1.2.3 Maximum permissible conductor temperature for short term operations including permissible duration of such short-term operation shall also be furnished by the bidder in the GTP Schedule.

1.2.4 The UTS of conductor at room temperature and at elevated temperature (i.e. at the designed maximum steady state conductor temperature corresponding to the specified ampacity) shall be declared in the GTP Schedule & the same shall be achieved during testing. Further, UTS of conductor declared at elevated temperature shall not be less than 70% of UTS at room temperature declared in the GTP.

### 1.3 Sag-Tension Requirements

1.3.1 Sag of the offered HTLS conductor at designed maximum temperature should not be more than that specified in *Section-I*. Sag of the offered HTLS conductor at minimum temperature shall not be less than the minimum values specified in *section-I*.

1.3.2 Tension shall not exceed the maximum limit in all sag tension conditions specified in *Section-I*.

1.3.3 For the purpose of design calculations for GAP type HTLS conductor, temperature at everyday condition as specified in *Section-I* shall be considered as knee point temperature.

### 1.4 Current Carrying Capacity /Ampacity Requirements

The offered HTLS conductor shall be suitable to carry minimum specified Amperes of 50 Hz alternating current under the ambient conditions specified below & maximum conductor sag as specified in Section-I while satisfying other specified technical requirements/ parameters: -

Ambient Conditions	Parameter
Elevation above sea level	0 meter
Ambient temperature	45 <sup>0</sup> C
Solar absorption coefficient	0.8
Solar Radiation	1045 watt/sqm
Emissivity Constant	0.45

Wind velocity considering angle between wind & axis of conductor as 90 degrees	0.56 m/sec
Effective angle of incidence of sun's rays	90°

The calculations for Ampacity shall generally be based on IEEE Standard 738:2023 in SI units except otherwise specified herein.

For calculation of the radial temperature gradient within the conductor, effective thermal conductivity (kth) shall be considered as 1 watt/m-°C. Further, conductor sag at designed maximum temperature shall be calculated considering temperature of core corresponding to the designed maximum temperature of conductor shall be calculated, irrespective of the magnitude of radial temperature gradient.

AC resistance of the offered HTLS conductor shall be calculated on the basis of *Chapter-2, EPRI AC Transmission Line Reference Book – 200 kV and Above* or the method specified below:

$$R_{ac} = R_{dc} \times (1 + 0.00519 \times (mr)^n \times k_1 + k_2) \text{ where,}$$

$$mr = 0.3544938 / (R_{dc})^{1/2}$$

$$\text{if } mr < 2.8, \text{ then } n = 4 - 0.0616 + 0.0896 \times mr - 0.0513 \times (mr)^2$$

$$\text{if } mr > 2.8 < 5.0, \text{ then } n = 4 + 0.5363 - 0.2949 \times mr + 0.0097 \times (mr)^2$$

$$k_1 = \{\cos(90(d/D)^p)\}^{2.35} \text{ where,}$$

$$p = 0.7 + 0.11 \times mr - 0.04 \times mr^2 + 0.0094 \times mr^3$$

$$k_2 = \begin{aligned} &0.15 \text{ for single aluminium layer HTLS conductor} \\ &= 0.03 \text{ for three aluminium layer HTLS conductor} \\ &= 0.003 \text{ for two or four aluminium layer HTLS conductor} \\ &= 0 \text{ for composite core type HTLS conductor} \end{aligned}$$

where,

D= conductor outer diameter in metres

d = conductor inner diameter in metres

R<sub>dc</sub> = dc resistance of conductor at given temperature, ohms/ km

R<sub>ac</sub> = ac resistance of conductor at given temperature, ohms/ km

## 1.5 Sag Tension calculations

1.5.1 Sag-Tension calculations for the offered HTLS conductor can be carried out by using PLSCAD. Following values shall be considered for the purpose of sag-tension calculations: -

- (i) Final values of modulus of elasticity of Aluminium/ Aluminium Alloy/ Core, Coefficient of Linear Expansion of Aluminium/ Aluminium Alloy/ Core, Stress-Strain coefficients & Creep coefficients of aluminium/ aluminium alloy / core in the cable data (.wir file) used for calculation of sag in PLSCAD shall be based on either of the following: -
- Existing '.wir' files for offered conductor as available on PLS website.
  - A file derived from existing standard file for conductor of equivalent/ near equivalent stranding.
  - A file derived from type test conducted on conductor of same stranding.

In each of the above cases, proper justification in the form of test reports/ calculations/ print out of '.wir' file as available on PLS website, etc. shall be required to be submitted during detailed engineering.

- (ii) PLSCAD Sagging criteria/ conditions shall be based on the sag tension limits specified in Section-I and shall be carried out in a manner that the specified sag-tension limits are met in "After Creep" as well as in "After Load" condition.

1.5.2 Various conductor parameters (viz. modulus of elasticity, coefficient of linear expansion, stress-strain and creep, etc.) considered above in the sag tension calculation shall be verified during detailed engineering based on type tests conducted.

1.5.3 The Contractor shall also furnish stringing chart for the conductor (Initial & Final) for various temperatures starting from min. temperature to designed maximum temperature for all the spans as per detailed survey during detailed engineering.

1.5.4 In case of reconductoring projects, the Sag of offered HTLS conductor at design maximum temperature under nil wind condition shall not exceed the corresponding sag of existing conductor for any of the spans of the line(s) being reconducted.

## 1.6 Workmanship

1.6.1 All the conductor strands shall be smooth, uniform and free from all imperfections, such as spills and splits, cracks, die marks, scratches, abrasions, rust etc.

1.6.2 The finished conductor shall be smooth, compact, uniform and free from all imperfections including kinks (protrusion of wires), wire cross over, over riding, looseness (wire being dislocated by finger/hand pressure and/or unusual bangle noise on tapping), material inclusions, white rust, powder formation or black spot (on account of reaction with trapped rain water etc.), dirt, grit etc.

## 1.7 Joints in Wires

### 1.7.1 Aluminium/ Aluminium Alloy Wires

1.7.1.1 During stranding, no Aluminium/ Aluminium Alloy wire welds shall be made for the purpose of achieving the required conductor length.

1.7.1.2 No joint shall be permitted in the individual wires in the outer most layer of the finished conductor. However, joints are permitted in the inner layer(s) of the conductor unavoidably broken during stranding provided such breaks are not associated with either inherently defective wire or with the use of short lengths of Aluminium/ Aluminium Alloy wires. Such joints shall not be more than four (4) per conductor length and shall not be closer than 15 meters from joint in the same wire or in any other Aluminium Alloy wire of the completed conductor. A record of such joints for each individual length of the conductor shall be maintained by the Contractor for Employer's review.

1.7.1.3 Joints shall be made by electric butt welding, electric butt cold upset welding or cold pressure butt welding and shall withstand a stress of not less than the breaking strength of individual strand guaranteed.

### 1.7.2 Core/ Core Wires

There shall be no joint of any kind in the finished wire entering into the manufacture of the strand. There shall also be no joints or splices in any length of the completed core. However, during the production run, splicing of the galvanic protection barrier is allowed, provided diameter specifications are maintained.

## 1.8 Tolerances

Manufacturing tolerances on the dimensions to the extent of one percent ( $\pm 1\%$ ) shall be permitted for individual strands and the complete conductor. In case manufacturing tolerances more than one percent ( $\pm 1\%$ ) is proposed for individual strands of a particular conductor as per applicable Indian/ International standard, the same may be permitted subject to submission of supporting documents/ details by the Contractor while approval of GTP during detailed engineering.

In case of Polymer Matrix composite core, the tolerances shall be  $\pm 0.05$  mm as per ASTM B987.

## 1.9 Materials

The materials used for construction of the conductor shall be such that the conductor meets the specified technical and performance requirements.

1.9.1 **Aluminium/ Aluminium Alloy layers**

1.9.1.1 The material of outer layer of HTLS conductor shall be of high temperature resistant aluminum alloy manufactured by adding zirconium or any other suitable element(s) etc. to electrolytic aluminium or annealed aluminium (0 tempered) having purity not less than 99.5% and a copper content not exceeding 0.04%. The strands shall be manufactured through appropriate manufacturing process to ensure consistent electrical, mechanical and metallurgical properties under continuous high temperature operation. Bidder shall guarantee the chemical composition in the schedule GTP of BPS and also furnish description of the manufacturing process in the Bid.

1.9.1.2 In case of fully annealed type (0 tempered) aluminium strands, round wire/ trapezoidal/ Z-shaped wire shall be accepted.

1.9.2 **Core**

1.9.2.1 The core wire strand(s) shall be of galvanized steel/ Invar wires/ or Zinc-5% Aluminium–Mischmetal alloy coated steel/ Invar wires or aluminium clad steel/ Invar wires or composite materials etc. and shall have properties conforming to the technical performance requirements of the finished conductor. In case of Polymer Matrix Composite (PMC) core, only Single strand i.e. solid, PMC core shall be acceptable. In case, the temperature of core corresponding to the designed maximum temperature of the offered HTLS conductor exceeds 180<sup>o</sup> C, ordinary zinc coating/ galvanizing of the Steel/ Invar core wires shall not be accepted and only aluminium clad or Mischmetal coated wires shall be permitted. Bidder shall furnish properties and composition of the core wire strand(s) in the schedule GTP of BPS. The properties & composition of core wires guaranteed by the bidder shall be based on the relevant published Indian/International Standards, wherever applicable. Offered polymer matrix composite core shall meet the requirement of “Galvanic Protection Barrier Layer Thickness test” as per ASTM B987. However, in no case, the guaranteed values for torsion & elongation of Steel/ Invar core of the offered HTLS Conductor shall be less than as indicated below:

Minimum No. of twists in gauge length equal to 100 times the dia. of wire which the strand can withstand in the torsion test (before stranding) *	12
Minimum elongation (%) of the core strand (after stranding) for a gauge length of 250 mm (at break)	1.5
<i>*A reduction of 2 number of twists is permitted for after stranding values.</i>	

1.9.2.2 The zinc used for galvanizing of core (if used) shall be electrolytic High-Grade Zinc of 99.95% purity. It shall conform to and satisfy all the requirements of IS 209. The

minimum mass of zinc coating shall conform to the requirements of relevant standard. Zinc-5% Aluminium–Mischmetal alloy coating, if used, shall conform to and satisfy all the requirements of ASTM B 803/ B 958.

- 1.9.2.3 The aluminium cladding of wires shall be of aluminum having purity not less than 99.5 % and shall be thoroughly bonded to the core wire strand(s). The minimum conductivity of offered aluminium clad wire shall be 14% of IACS. The minimum thickness of aluminium cladding shall be 3% & 5% of nominal wire diameter, for 14% & 20% IACS conductivity respectively.
- 1.9.2.4 Where Polymer Matrix composite material is offered for core, the material shall be either of high strength grade or extra high strength grade as per ASTM B987. The materials shall be of such proven quality that its properties are not adversely influenced by the normal operating conditions of transmission line in tropical environment conditions as experienced by the existing line. The bidder shall provide adequate details including specifications/ test reports/ operating experience details/ performance certificates etc. in support of the suitability of the offered materials.

#### **1.10 Standard Length**

- 1.10.1 The standard length of the conductor shall be indicated in the guaranteed technical particulars of offer. A tolerance of  $\pm 5\%$  on the standard length offered by the Bidder shall be permitted. Standard Length shall not be more than 2500 meters. All lengths outside this limit of tolerance shall be treated as random lengths.
- 1.10.2 Random lengths will be accepted provided no length is less than 70% of the standard length and the total quantity of such random lengths shall not be more than 10% of the total quantity ordered. At no point, the cumulative quantity supplied of such random lengths shall be more than 12.5% of the total cumulative quantity supplied including such random lengths. However, the last 20% of the quantity ordered shall be supplied only in standard lengths as specified except for one last drum, which may be supplied with any random length necessary to complete the supply of ordered conductor quantity.
- 1.10.3 During implementation stage, supply of HTLS conductors by contractor in 3 or 4 different standard lengths depending upon actual tower schedule/ site conditions, may be permitted based on approval by site in-charge.
- 1.10.4 Bidder shall also indicate the maximum single length, above the standard length, he can manufacture in the guaranteed technical particulars of offer. This is required for special stretches like river crossing etc. The Employer reserves the right to place orders for the above lengths on the same terms and conditions applicable for the standard lengths during the pendency of the Contract.

## 2.0 Tests and Standards

### 2.1 Type Tests

#### 2.1.1 Type Tests on Stranded Conductor/ Core

The following tests shall be conducted on sample/ sample(s) of the conductor required under the package from manufacturing works from which the conductor is to be manufactured & supplied: -

##### i) On complete Conductor

a)	DC resistance test on stranded conductor	Annexure-A
b)	UTS test on stranded conductor i) at Room Temperature and ii) at Elevated Temperature	Annexure-A
c)	Radio interference voltage test (dry) (Applicable for 220KV & above voltage rating)	Annexure-A
d)	Corona extinction voltage test (dry) (Applicable for 220KV & above voltage rating)	Annexure-A
e)	Stress-Strain test on stranded conductor and core	IEC 61089
f)	creep test on stranded conductor	Annexure-A
g)	Sheaves Test (Applicable for Composite core conductors only)	Annexure-A
h)	Radial Crush Test	Annexure-A
i)	Torsional Ductility Test	Annexure-A
j)	Aeolian Vibration Test	Annexure-A
k)	Temperature Cycle Test	Annexure-A

##### ii) On Conductor Strand/core

a)	Heat resistance test on Aluminium Alloy strands (Not applicable for Annealed Aluminium)	Annexure-A
b)	Bending test on aluminium clad core strands (if applicable)	Annexure-A
c)	Compression test on aluminium clad core strands (if applicable)	Annexure-A
d)	Coefficient of linear expansion on core	Annexure-A
e)	Brittle fracture test on Polymer composite core (if applicable)	Annexure-A
f)	Bending test on composite core (if applicable)	Annexure-A

2.1.2 Type tests specified under Clause 2.1.1 shall not be required to be carried out if a valid test certificate is available for the offered design. The test certificate shall be considered valid if,

- i) Tests conducted earlier is either conducted in accredited laboratory (accredited based on ISO/ IEC vide 25/ 17025 or EN 45001 by the National accreditation body of the country where laboratory is located) or witnessed by the representative(s) of POWERGRID or utility and
- ii) Type test reports contain valid Calibration reports of the relevant testing equipment and information pertaining to ratings, the relevant drawings, model number, test circuit, calculations (if any), photos, acceptance criteria/ values specified in Technical Specification/relevant standards (IS/ IEC) and compliance to the same and
- iii) Tests conducted on the samples of conductor manufactured from same manufacturing works within 7 (seven) years as on the date of NOA for the package.

Further, test certificates of samples manufactured from same manufacturing works shall also be considered valid, if the same has already been approved/ accepted by POWERGRID & tests have been conducted within the abovementioned validity period.

In case the tests have been conducted earlier than the above stipulated period or carried out on samples manufactured from any other manufacturing works or in case of revision/ amendment in the provisions/ test procedure of the IS/ IEC as referred in the TS or in the event of any discrepancy in the test report (i.e. due to non-inclusion of valid calibration certificate, desired information etc. or any test not applicable due to any design/ material/ manufacturing process change including substitution of components or due to non-compliance with the requirement stipulated in the Technical Specifications), the tests shall be conducted by the supplier at no extra cost to the purchaser.

## 2.2 Acceptance Tests

a)	Visual and dimensional check on drum	Annexure-A
b)	Visual check for joints scratches etc. and length measurement of conductor by rewinding	Annexure-A
c)	Dimensional check on core/core strands and Aluminium/ Aluminium Alloy strands	Annexure-A
d)	Check for lay-ratios of various layers	Annexure-A
e)	Galvanising & adherence of coating test on core strands (if applicable)	Annexure-A

f)	Coating Test on Zinc-5% Al-Mischmetal alloy coating (if applicable)	ASTM B803/ B958
g)	Adherence of Coating Test on Zinc-5% Al-Mischmetal alloy coating (if applicable)	ASTM B803/ B958
h)	Thickness & adherence of aluminum cladding on aluminium clad strands	Annexure-A
i)	Torsion and Elongation tests on core strands/ composite core	Annexure-A
j)	Breaking load test on core strands and Aluminium/ Aluminium Alloy strands	Annexure-A
k)	Wrap test on Aluminium Alloy strands (Not applicable for Annealed aluminium wires)	IEC 62641
l)	Wrap test on core strands (Not applicable for composite core)	IEC 63248
m)	Minimum conductivity test on thermal resistant Aluminium Alloy/ Aluminium strands	Annexure-A
n)	Procedure qualification test on welded joint of Aluminium/ Aluminium Alloy wire	Annexure-A
o)	Heat resistance test on Aluminium Alloy strands (Not applicable for Annealed Aluminium)	Annexure-A
p)	Ageing test on filler (if applicable)	Annexure-A
q)	Minimum conductivity test on aluminium clad core strands (if applicable)	Annexure-A
r)	Glass transition temperature test on Polymer composite core/ core strands (if applicable)	Annexure-A
s)	Flexural Strength test on Polymer composite core/ core strands (if applicable)	Annexure-A
t)	Bending test on composite core (if applicable)	Annexure-A
u)	Galvanic Protection Barrier Layer Thickness test on composite core	ASTM B987
<p>Note:</p> <p>1) All the above tests except (n) shall be carried out on Aluminium Alloy and core strands after stranding only.</p> <p>2) Wrap test on Aluminium/ Aluminium Alloy strands is only applicable for round wires.</p>		

### 2.3 Routine Test

a)	Check to ensure that the joints are as per Specification
b)	Check that there are no cuts, fins etc., on the strands
c)	Check that drums are as per Specification

d)	All acceptance tests as mentioned above to be carried out on 10 % of drums
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#### 2.4 Tests During Manufacture

a)	Chemical analysis of zinc used for galvanizing	Annexure-A
b)	Chemical analysis of Aluminium alloy used for making Aluminium Alloy strands	Annexure-A
c)	Chemical analysis of Core strands (not applicable on composite core)	Annexure-A

#### 2.5 Testing Expenses

2.5.1 In the event of type testing, bidder shall ensure that adequate facilities are available in the proposed laboratories and the tests can be completed in these laboratories within the time schedule.

2.5.2 In case of failure in any type test, the Contractor is either required to manufacture fresh sample lot and repeat the entire test successfully once or repeat that particular type test three times successfully on the sample selected from the already manufactured lot at his own expenses. In case a fresh lot is manufactured for testing then the lot already manufactured shall be rejected.

If repeat type tests are required to be conducted, then all the expenses for deputation of Inspector/ Employer's representative shall be deducted from the contract price. Also, if on receipt of the Contractor's notice of testing, the Employer's representative does not find material/ testing facilities to be ready for testing the expenses incurred by the Employer for re-deputation shall be deducted from contract price.

2.5.3 The Contractor shall intimate the Employer about carrying out of the type tests along with detailed testing programme at least 3 weeks in advance (in case of testing in India) and at least 6 weeks in advance (in case of testing abroad) of the schedule date of testing during which the Employer will arrange to depute his representative to be present at the time of carrying out the tests.

2.5.4 The entire cost of testing for the acceptance and routine tests and Tests during manufacture specified herein shall be treated as included in the quoted unit price of conductor, except for the expenses of the inspector/ Employer's representative.

#### 2.6 Additional Tests

- 2.6.1 The Employer reserves the right of having at his own expenses any other test(s) of reasonable nature carried out at Supplier's premises, at site or in any other place in addition to the aforesaid type, acceptance and routine tests to satisfy himself that the materials comply with the Specifications.
- 2.6.2 The Employer also reserves the right to conduct all the tests mentioned in this specification at his own expense on the samples drawn from the site at Supplier's premises or at any other test centre. In case of evidence of non-compliance, it shall be binding on the part of Contractor to prove the compliance of the items to the technical specifications by repeat tests, or correction of deficiencies, or replacement of defective items all without any extra cost to the Employer.
- 2.7 Sample Batch for Type Testing**
- 2.7.1 The Contractor shall offer material for selection of samples for type testing only after getting Quality Assurance Plan approved from Employer's Quality Assurance Deptt. The sample shall be manufactured strictly in accordance with the Quality Assurance Plan approved by Employer.
- 2.7.2 The Contractor shall offer at least three drums for selection of sample required for conducting all the type test.
- 2.7.3 The Contractor is required to carry out all the acceptance tests successfully in presence of Employer's representative before sample selection.
- 2.8 Test Reports**
- 2.8.1 Copies of type test reports shall be furnished in at least three copies along with one original. One copy will be returned duly certified by the Employer only after which the commercial production of the material shall start.
- 2.8.2 Record of routine test reports shall be maintained by the Contractor at his works for periodic inspection by the Employer's representative.
- 2.8.3 Test Certificates of tests during manufacture shall be maintained by the Contractor. These shall be produced for verification as and when desired by the Employer.
- 2.9 Inspection**
- 2.9.1 The Employer's representative shall at all times be entitled to have access to the works and all places of manufacture, where conductor shall be manufactured and representative shall have full facilities for unrestricted inspection of the Supplier's works, raw materials and process of manufacture for conducting necessary tests as detailed herein.

- 2.9.2 The Contractor shall keep the Employer informed in advance of the time of starting and of the progress of manufacture of conductor in its various stages so that arrangements can be made for inspection.
- 2.9.3 No material shall be dispatched from its point of manufacture before it has been satisfactorily inspected and tested, unless the inspection is waived off by the Employer in writing. In the latter case also the conductor shall be dispatched only after satisfactory testing for all tests specified herein have been completed.
- 2.9.4 The acceptance of any quantity of material shall in no way relieve the Contractor of any of his responsibilities for meeting all requirements of the Specification, and shall not prevent subsequent rejection if such material is later found to be defective.

## **2.10 Test Facilities**

- 2.10.1 The following additional test facilities shall be available at the Supplier's works:
- Calibration of various testing and measuring equipment including tensile testing machine, resistance measurement facilities, burette, thermometer, barometer etc.
  - Standard resistance for calibration of resistance bridges.
  - Finished conductor shall be checked for length verification and surface finish on separate rewinding machine at reduced speed (variable from 8 to 16 meters per minute). The rewinding facilities shall have appropriate clutch system and free of vibrations, jerks etc. with traverse laying facilities.

## **2.11 Packing**

- 2.11.1 The conductor shall be supplied in non-returnable, strong, wooden drums provided with lagging of adequate strength, constructed to protect the conductor against all damage and displacement during transit, storage and subsequent handling and stringing operations in the field. The Supplier shall be responsible for any loss or damage during transportation handling and storage due to improper packing. The drums shall generally conform to IS 1778, except as otherwise specified hereinafter.
- 2.11.2 The drums shall be suitable for wheel mounting and for letting off the conductor under a minimum controlled tension of the order of 5 KN.
- 2.11.3 The standard drawing of the wooden/steel drum for HTLS conductors is enclosed with the specification. The Bidder should submit drum drawing during detailed engineering for approval after incorporating standard length and dimensions required as per standard drawing.

- 2.11.4 For conductor, one standard length shall be wound on each drum.
- 2.11.5 All wooden components shall be manufactured out of seasoned soft wood free from defects that may materially weaken the component parts of the drums. Preservative treatment shall be applied to the entire drum with preservatives of a quality which is not harmful to the conductor.
- 2.11.6 The flanges shall be of two-ply construction with each ply at right angles to the adjacent ply and nailed together. The nails shall be driven from the inside face flange, punched and then clenched on the outer face. The thickness of each ply shall not vary by more than 3mm from that indicated in the figure. There shall be at least 3 nails per plank of ply with maximum nail spacing of 75mm. Where a slot is cut in the flange to receive the inner end of the conductor the entrance shall be in line with the periphery of the barrel.
- 2.11.7 The wooden battens used for making the barrel of the conductor shall be of segmental type. These shall be nailed to the barrel supports with at least two nails. The battens shall be closely butted and shall provide a round barrel with smooth external surface. The edges of the battens shall be rounded or chamfered to avoid damage to the conductor.
- 2.11.8 Barrel studs shall be used for the construction of drums. The flanges shall be holed and the barrel supports slotted to receive them. The barrel studs shall be threaded over a length on either end, sufficient to accommodate washers, spindle plates and nuts for fixing flanges at the required spacing.
- 2.11.9 Normally, the nuts on the studs shall stand protruded of the flanges. All the nails used on the inner surface of the flanges and the drum barrel shall be counter sunk. The ends of barrel shall generally be flushed with the top of the nuts.
- 2.11.10 The inner cheek of the flanges and drum barrel surface shall be painted with a bitumen based paint.
- 2.11.11 Before reeling, card board or double corrugated or thick bituminised water-proof bamboo paper shall be secured to the drum barrel and inside of flanges of the drum by means of a suitable commercial adhesive material over which HDPE sheet to be provided. In case of steel drum, for securing HDPE sheet onto the bamboo paper & drum flanges, the HDPE sheet shall be secured onto the drum by means of a commercial adhesive/self-locking nylon cable zip ties such that there is no protrusion above the general surface that may cause damage to the conductor strands. After reeling the conductor, the exposed surface of the outer layer of conductor shall be wrapped with thick plastic sheet secured using adhesive tapes to preserve the conductor from dirt, grit and damage during storage, transport and handling. Medium grade craft/crepe/polythene paper shall be used in between the layers of conductor. Additionally, in case of Annealed

aluminium being used for aluminium layers of offered HTLS conductor, medium grade kraft paper of 90 to 100 mm width shall be wrapped over HTLS conductor during production and re-winding such that the no conductor layer is directly in contact with other side, below & upper conductor layers in a drum.

- 2.11.12 A minimum space of 75 mm for conductor shall be provided between the inner surface of the external protective tagging and outer layer of the conductor.
- 2.11.13 Each batten shall be securely nailed across grains as far as possible to the flange, edges with at least 2 nails per end. The length of the nails shall not be less than twice the thickness of the battens. The nails shall not protrude above the general surface and shall not have exposed sharp, edges or allow the battens to be released due to corrosion.
- 2.11.14 The nuts on the barrel studs shall be tack welded on the one side in order to fully secure them. On the second end, a spring washer shall be used.
- 2.11.15 A steel collar shall be used to secure all barrel studs. This collar shall be located between the washers and the steel drum and secured to the central steel plate by welding.
- 2.11.16 Outside the protective lagging, there shall be minimum of two binder consisting of hoop iron/galvanised steel wire. Each protective lagging shall have two recesses to accommodate the binders.
- 2.11.17 The conductor ends shall be properly sealed and secured on the side of one of the flanges to avoid loosening of the conductor layers during transit and handling.
- 2.11.18 As an alternative to wooden drum, Supplier may also supply the conductors in returnable/ non-returnable painted steel drums. After preparation of steel surface according to IS 9954, synthetic enamel paint shall be applied after application of one coat of primer. Wooden/Steel drum will be treated at par for evaluation purpose and accordingly the Bidder should quote in the package.
- 2.11.19 In case of returnable steel drums for conductor, following clauses shall apply:
- a) The Ownership of the empty conductor drums shall lie with the conductor Supplier who shall ultimately take back the empty conductor drum from the Project site(s) from the erection contractor's designated stores after the running out of conductor from the drum.
  - b) The erection contractor shall intimate the Conductor supplier and Employer regarding empty steel drums at their designated stores. Necessary coordination for taking back the empty steel drums in this regard shall be done by the Conductor Supplier with the erection Contractor.

- c) The empty drum shall be taken back by the conductor supplier from the stores of erection contractor as & when these are available after usage of conductor. Conductor Supplier shall be required to take back the empty steel drum within a period of one month from date of information by erection contractor regarding availability of the drums at erection contractor stores. However, drums of spare conductor shall not be returned to the conductor Supplier as these may be used for storage of spare conductor by the Employer.
- d) The steel drums may get damage and wear & tear due to transportation, normal handling & operation at site, which shall be rectified by the conductor Contractor before re-use. However, 2% of the total drums shall not be returned on account of damages/ wastage for which no compensation will be payable. The wastage beyond 2% shall be reimbursed by Erection Contractor.

2.11.20 As an alternative to outer wooden lagging, in case of returnable/ non-returnable steel drums, solid polypropylene sheet (of min 3mm thickness) can be used for outer covering of conductor. In case of PP sheets are proposed to be used by the Contractor, the conductor Contractor shall supply two nos. additional binders per drum for re-wrapping PP sheet with each lot of conductor and 5 nos. crimping machines with the first lot of conductor for crimping the binders at site.

## 2.12 Marking

Each drum shall have the following information stenciled on it in indelible ink along with other essential data:

- (a) Contract/Specification number.
- (b) Name and address of the consignee.
- (c) Manufacturer's name and address.
- (d) Drum number
- (e) Size of conductor
- (f) Length of conductor in meters
- (g) Arrow marking for unwinding
- (h) Position of the conductor end (For Wooden Drums only)
- (i) Number of turns in the outer most layer.
- (j) Gross weight of the drum (with protective lagging in case of wooden drums) including conductor.

- (k) Weight of empty drum (with protective lagging in case of wooden drums).
- (l) Net weight of the conductor in the drum.
- (m) CIP No.

The above should be indicated in the packing list also.

### 2.13 Verification of Conductor Length

The Employer reserves the right to verify the length of conductor after unreeling at least ten (10) percent of the drums in a lot offered for inspection.

### 2.14 Standards

2.14.1 The conductor shall conform to the following Indian/International Standards, which shall mean latest revisions, with amendments/changes adopted and published, unless specifically stated otherwise in the Specification.

2.14.2 In the event of the supply of conductor conforming to standards other than specified, the Bidder shall confirm in his bid that these standards are equivalent to those specified. In case of award, salient features of comparison between the standards proposed by the Contractor and those specified in this document will be provided by the Contractor to establish their equivalence.

Sl. No.	Indian Standard	Title	International Standard
1	IS 209:1992	Specification for Zinc	
2	IS 398:1982	Specification for Aluminium Conductors for Overhead Transmission Purposes	
3	IS 398 (Part-II): 1990	Aluminum Conductor Galvanised Steel Reinforced	
4	IS 398 (Part-IV)	Aluminium Alloy stranded conductor	
5	IS 398 (Part-V): 1992	Aluminum Conductor Galvanised Steel-Reinforced For Extra High Voltage (400 KV) and above	
6	IS 1778:1980	Reels and Drums for Bare Conductors	
7	IS 1521:1991	Method of Tensile Testing of Steel Wire	
8	IS 2629:1990	Recommended Practice for Hot Dip Galvanising of Iron and Steel	
9	IS 2633:1992	Method of Testing Uniformity of Coating on Zinc Coated Articles	
10	IS 4826:1992	Galvanised Coating on Round Steel Wires	

11	IS 6745:1990	Methods of Determination of Weight of Zinc Coating of Zinc Coated Iron and Steel Articles	
12	IS 8263:1990	Method of Radio Interference Tests on High Voltage Insulators	
13	IS 9997:1988	Aluminium Alloy Redraw Rods	
14		Coated or clad metallic wire for concentric lay stranded conductors	IEC 63248
15		Aluminium and Aluminium Alloy Wires for Concentric Lay Stranded Conductors	IEC 62641
17		Method of measurement of resistivity of metallic materials	IEC 60468
18		IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors	IEEE 738:2023
20		Overhead electrical conductors – Formed wire, concentric lay, stranded conductors	IEC 62219
21		Concentric lay stranded overhead electrical conductors containing one or more gap(s)	IEC 62420
22		Standard Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes	ASTM B609
23		Standard Specification for High Strength Zinc-5% Aluminium-Mischmetal alloy coated steel core wire for use in Overhead Electrical Conductors	ASTM B803
24		Standard Specification for Concentric Lay Stranded Aluminum Conductors, Coated Steel supported (ACSS)	ASTM B856
25		Standard Specification for Shaped Wire Compact Concentric Lay Stranded Aluminum Conductors, Coated Steel supported (ACSS/TW)	ASTM B857
26		Standard Specification for Extra-High Strength and Ultra-High Strength Zinc coated (Galvanized) steel core wire for Overhead Electrical Conductors	ASTM B957
27		Standard Specification for Extra-High Strength and Ultra-High Strength Class A Zinc-5% Aluminium-Mischmetal alloy coated steel core wire for use in Overhead Electrical Conductors	ASTM B958

28		Carbon Fibre Composite core (CFCC/TS) for use in Overhead Electrical Conductors	ASTM B987-20
29		Conductors for overhead lines – Aluminium Conductors Steel Supported (ACSS)	BS EN 50540
30		Standard Test Method for Dropping point of Lubricating Grease	ASTM D566
31		Standard Test Method for Dropping point of Lubricating Grease over wide temperature range	ASTM D2265

The standards mentioned above are available from: -

Reference Abbreviation	Name and Address
BS	British Standards, British Standards Institution 101, Pentonville Road, N - 19-ND, UK
IEC/CISPR	International Electro technical Commission, Bureau Central de la Commission, electro Technique internationale, 1 Rue de verembe, Geneva, SWITZERLAND
BIS/IS	Bureau Of Indian Standards. Manak Bhavan, 9, Bahadur Shah Zafar Marg, New Delhi - 110001. INDIA
ISO	International Organisation for Standardization. Danish Board of Standardization Danish Standardizing Sraat, Aurehoegvej-12 DK-2900, Heeleprup, DENMARK.
NEMA	National Electric Manufacture Association, 155, East 44th Street. New York, NY 10017, U.S.A.
ASTM	ASTM International 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA

Annexure-A

1 **DC Resistance Test on Stranded Conductor**

On a conductor sample of minimum 5m length two contact-clamps shall be fixed with a predetermined bolt torque. The resistance shall be measured by a Kelvin double bridge or using micro ohm meter of suitable accuracy by placing the clamps initially zero metre and subsequently one metre apart. The test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20<sup>0</sup> C as per IS 398 (Part-IV)/ (Part-V). The resistance corrected at 20<sup>0</sup> C shall conform to the requirements of this Specification.

2 **UTS Test on Stranded Conductor**

**i) UTS test on stranded conductor at room temperature\***

Circles perpendicular to the axis of the conductor shall be marked at two places on a sample of conductor of minimum 10m length between fixing arrangement suitably fixed by appropriate fittings on a tensile testing machine. The load shall be increased at a steady rate upto 50% of minimum specified UTS and held for one minute. The circles drawn shall not be distorted due to relative movement of strands. Thereafter the load shall be increased at steady rate to minimum UTS and held for one minute. The Conductor sample shall not fail during this period. The applied load shall then be increased until the failing load is reached and the value recorded.

*In case, fracture occurs within 1 cm of the end fittings and the tensile strength falls below the specified breaking strength requirements, a retest, up to a total of three tests, may be made.*

*\*The test is to be conducted at ambient temperature, between minimum and maximum ambient temperature of 0<sup>0</sup>C and 50<sup>0</sup>C respectively.*

**ii) UTS test on stranded conductor at elevated temperature**

UTS Test on Stranded Conductor shall be conducted as per Sl. no. 2(i) of this Annexure-A specified above keeping conductor temperature at the designed maximum temperature.

3 **Corona Extinction Voltage Test**

The sample assembly with each conductor of 5 m length shall be strung as per the configuration shown in the Table below:

Line Configuration	No of conductors per Bundle	Sub-conductor Spacing (mm)	Maximum Height of the conductor above ground (m)	Minimum Corona extinction voltage (kV)

220 kV with HTLS conductor	1	N.A.	7	154
400 kV with twin HTLS conductor	2	NA	8.84	320

The sample assembly when subjected to power frequency voltage under dry condition shall have a corona extinction voltage of not less than the values indicated in the table above. There shall be no evidence of corona on any part of the samples. The test should be conducted without corona control rings. However, small corona control rings may be used to prevent corona in the end fittings. The atmospheric conditions during testing shall be recorded and test results should be corrected for standard atmospheric conditions.

**4 Radio Interference Voltage Test**

Under the conditions as specified under *Sl. no. 3 of this Annexure-A*, the conductor samples shall have radio interference voltage below 1000 microvolts at one MHz when subjected to 50 Hz AC voltage of 305 kV line to ground under dry conditions for 400kV and 154 kV line to ground under dry conditions for 220 kV. This test may be carried out with corona control rings and arcing horns. The test procedure shall be in accordance with IEC 60437.

**5 Creep test on Stranded Conductor**

One conductor samples of length equal to at least  $100 \times d + 2 \times a$  (where, d is the conductor diameter and a is the distance between the end fitting and the gauge length) shall be strung at tension equal to 25 % of conductor UTS. The distance, a, shall be at least 25 % of the gauge length or 2 m whichever is the smaller.

The conductor temperature shall be maintained at 20<sup>0</sup> C for 1000 hours. The elongation/ creep strain of the conductor during this period shall be measured and recorded at end of 1-hour, 10-hour, 100-hour and subsequently every 100 hour upto 1000 hours time period.

The Supplier shall furnish details of creep characteristic in respect of the conductor based on laboratory test and other laboratory investigations/ experiments conducted on conductor and shall indicate creep strain values corresponding to 1 month, 6-months, 1 year, 10 years & 20 years creep at everyday tension & room temperature.

**6 Sheaves Test (applicable for Composite core conductors only)**

The conductor sample of minimum length of 35 meter shall be tensioned at 20 % of the UTS; pulley diameter shall be not more than 32 times that of the conductor; angle between the pulleys shall be 20 degrees. The conductor shall

be passed over the pulleys 36 times at a speed of 2 m/sec. After this test, UTS test on the conductor shall be carried out as per Sl. no. 2(i) of this Annexure-A. In the case of polymer composite core conductors, the core shall be inspected for damage by subjecting the core to a dye penetration test as per ASTM B987 section 14. Dye penetrant exposure time shall be  $30 \pm 0$  minutes.

7 **Radial Crush Test**

A section of conductor is to be crushed between two six-inch steel plates. Load shall be held at 350 Kgs for 1 minute and then released. Core strands shall be subsequently disassembled and tensile tested. Core strands shall exhibit full strength retention vis-a-vis guaranteed breaking strength of core wires (after stranding).

8 **Torsional Ductility Test**

The conductor sample of minimum 1500 times diameter of conductor core shall be loaded to 20% of UTS and then rotated in increasing steps of  $\pm 180$  deg. The entire conductor shall withstand at least 16 such rotation and there shall not be any damage to Aluminium/ Aluminium Alloy or core wires.

In case of composite core conductors, after 4 rotations or after separation of aluminium strands, the aluminium wires shall be cut and removed from the conductor and the exposed core shall be twisted and shall withstand upto 16 rotations.

9 **Aeolian Vibration Test**

The conductor and supporting hardware shall be loaded to 25% of UTS. A dynamometer, load cell, calibrated beam or other device shall be used to measure the conductor tension. Some means should be provided to maintain constant tension to allow for temperature fluctuations during the testing. The overall span between system terminations shall be a minimum of 30 m. The span shall be supported at a height such that the static sag angle of the cable to horizontal is  $(1.5 \pm 0.5)$  deg in the active span. Means shall be provided for measuring and monitoring the mid-loop (antinode) vibration amplitude at a free loop, not a support loop. An electronically controlled shaker shall be used to excite the conductor in the vertical plane. The shaker armature shall be securely fastened to the conductor so it is perpendicular to the conductor in the vertical plane. The shaker should be located in the span to allow for a minimum of six vibration loops between the suspension assembly and the shaker

The test shall be carried out at one or more resonance frequencies (more than 10 Hz). The amplitude (peak-to-peak) at the antinode point shall be one third of conductor diameter. The assembly shall be vibrated for not less than 10 million cycles without any failure. After the test, the conductor should not

exhibit any damage (broken strands). The conductor shall be tested as per *Sl. no. 2(i) of this Annexure-A* to demonstrate that it retains at least 95% UTS.

#### 10 **Temperature Cycle Test**

The purpose of this test is verification of degradation characteristics of metallic and non-metallic material when subjected to thermal cycling. Temperature cycling can create large internal stresses due to thermal expansion mismatch between constituents.

Test Methods: -

- Conductor Sample of minimum 10m length.
- Mechanical tension, 20 % UTS, marks on the conductor at the edge of the conductor.
- 100 cycles from room temperature up to designed maximum temperature. Hold at designed maximum temperature  $\pm 2.5^{\circ}$  C for 5 minutes.
- After the above mentioned 100 cycle, the Mechanical tension shall be increased to 70% UTS at room temperature and kept at this tension for 24 hours. Thereafter, release to 20% UTS
- This cycling test shall be repeated 5 times.
- During the test, temperature of connectors, conductor and resistance are recorded according to ANSI C 119.
- A breaking load test as per *Sl. no. 2(i) of this Annexure-A* shall be applied at the end of the test. Conductor strength has to be higher than 95 % UTS.
- In case of polymer composites, after thermal cycling, the flexural strength and the Glass Transition temperature ( $T_g$ ) shall not degrade by more than 10 % of the value guaranteed in GTP. Flexural strength shall be obtained on the basis of test procedure indicated at *Sl. no. 33 of this Annexure-A*. The value of  $T_g$  after the test, shall however, in no case be less than the temperature of core corresponding to the designed maximum temperature of conductor.

#### 11 **Heat Resistance test on Aluminium Alloy Strands (as Type Test)** ***(Not applicable for Annealed Aluminium Strands)***

The 400 h test shall be carried out as per Clause 6.4.8.2 of IEC 62641 except that specimen shall be taken from all the wires of a conductor under test. The breaking strength of the wire after heating shall not be less than the 90% of the breaking strength before heating.

#### 12 **Heat Resistance test on Aluminium Alloy Strands (as Acceptance Test)** ***(Not applicable for Annealed Aluminium Strands)***

The 1 h test shall be carried out as per Clause 6.4.8.2 of IEC 62641 except that specimen shall be taken from all the wires of a conductor under test. The breaking strength of the wire after heating shall not be less than the 90% of the breaking strength before heating.

**13 Bending test on aluminium clad core strands (if applicable)**

A sample of aluminium clad core strand measuring 30 cm in length shall be subject to bending with help of a vise. The vised length of wire should be 5 cm and radius of bend 4.8 mm. The bending should be first 90 degrees left and 90 degree right. After this operation the strand should cut at the bending point. There should be no separation of core and aluminium at the bending point after this operation.

**14 Compression test on aluminium clad core strands (if applicable)**

A sample of aluminium clad core strand 10 mm in length is to be compressed by a plate with a load of 3600 kgs. The aluminium clad core strand should not break.

**15 Coefficient of linear expansion for core**

A minimum length of 10m of entire core (intact) shall be tested. The temperature and elongation on a sample shall be continuously measured and recorded at interval of approximately 15<sup>0</sup> C from room temperature to the temperature of core corresponding to the designed maximum temperature by changing the temperature by suitable means. Coefficient of linear expansion shall be determined from the measured results.

**16 Brittle fracture test on polymer Composite Core (if applicable)**

The core sample shall be tensioned to approx. 25 % of UTS with simultaneous application of 1N-HNO<sub>3</sub> acid directly in contact with naked polymer composite core for 96 hrs. The contact length of acid shall not be less than 40mm and thickness around the core not less than 10mm. After 96 hours, the core shall withstand UTS test as per ASTM B 987.

**17 Bending Test on Composite Core (as Type Test)**

Bending test on composite core before stranding shall be performed as per ASTM B987/B987M-20 on composite core samples taken from composite core at conductor manufacturing unit before stranding of conductor. Alternatively, supplier may carry out bending test on composite core before stranding on the samples taken at the core manufacturing unit, from the same reel being supplied to conductor manufacturer subject to proper traceability of the same at the conductor manufacturers works.

Bending test on composite core shall also be performed as per ASTM B987/ B987M-20 on composite core samples taken from stranded conductor. For test after stranding the diameter of cylindrical mandrel shall be as following:

For high strength grade composite core: 60 times the diameter of composite core.

For Extra high strength grade composite core: 70 times the diameter of composite core.

**18 Visual and Dimensional Check on Drums**

The drums shall be visually and dimensionally checked to ensure that they conform to the approved drawings.

**19 Visual Check for Joints, Scratches etc. and Length Measurement of Conductor by Rewinding**

Conductor drums shall be rewound in the presence of the Employer. The Employer shall visually check for scratches, joints etc. and that the conductor generally conform to the requirements of this Specification. Ten percent (10%) drums from each lot shall be rewound in the presence of the Employer's representative.

**20 Dimensional Check on Core /Core Strands and Aluminium/ Aluminium Alloy Strands**

The individual strands shall be dimensionally checked to ensure that they conform to the requirement of this Specification. Diameter of formed wires shall be determined as per clause 6.4.2.3 of IEC 62641.

**21 Check for Lay-ratios of Various Layers**

The lay-ratios of various layers shall be checked to ensure that they conform to the guaranteed values furnished by the Contractor.

**22 Galvanising & adherence of coating Test on Core Strands (If applicable)**

The test procedure shall be as per clause 7.4.5.1.1 & 7.4.5.2.1 of IEC 63248. The material shall conform to the requirements of this Specification. Mandrel diameter for adherence test shall be four times the diameter of steel wire.

**23 Thickness & adherence of Aluminum cladding on aluminum clad Strands (if applicable)**

The test procedure shall be as per clause 7.4.5.1.2 & 7.4.5.2.2 of IEC 63248. The material shall conform to the requirements of this Specification. Mandrel diameter for adherence test shall be five times the diameter of al clad wire.

24 **Torsion and Elongation Tests on Core Strands / Composite core**

The test procedures for Torsion and Elongation Tests on Core Strands shall be as per clause No. 7.4.4.1 and 7.4.3.4 of IEC 63248 respectively. In torsion test, the number of complete twists before fracture shall not be less than the value specified in the GTP on a length equal to 100 times the standard diameter of the strand. In case test sample length is less or more than 100 times the stranded diameter of the strand, the minimum number of twists will be proportioned to the length and if number comes in the fraction then it will be rounded off to next higher whole number. In elongation test, the elongation at fracture of the strand shall not be less than the value specified in the GTP for a gauge length of 250 mm.

In case of composite core HTLS conductor, the following procedure shall be applicable: -

i) **Elongation Test**

The elongation of the composite core sample shall be determined using extensometer. The load along the core shall be gradually increased. The elongation achieved on reaching the tensile strength of the core shall not be less than the value guaranteed in the GTP.

ii) **Torsion Test**

The purpose of the test is to determine the resilience of the composite core to twisting and to show that after the composite core has experienced the prescribed twisting, it will not crack or have a loss in tensile strength due to the twisting. The sample length shall be such that the gauge length in between the gripping fixtures is 170 times the diameter of the core in case of High Strength Grade composite cores and 340 times the diameter of the composite core in case of Extra High strength composite core. However, the gauge length shall not be more than 4m. One grip shall then be fixed so that it does not twist and the other end shall be twisted a full 360 degrees and then fixed in this position for 2 minutes. Once the twist time is completed, the core is untwisted and inspected for any crazing or other damage. If no damage is observed, the composite core is then tensile tested to failure and the final load recorded. For the test to be accepted, the composite core must withstand at least 100% of its rated tensile strength. Two samples need to be completed in order to satisfy the testing requirement.

25 **Breaking load test on Aluminium/ Aluminium Alloy & Core Strands/ Composite core**

The above test shall be carried out as per IEC 62641/63248 except in case of Composite core which may be tested as per IEC 63248 or other relevant Indian/ International standards. The results shall meet the requirements of this specification.

26 **Minimum Conductivity test on Thermal Resistant Aluminium Alloy/ Aluminium strands**

Resistivity test as per IEC 60468 shall be conducted to confirm minimum conductivity as per specification requirement.

27 **Procedure Qualification test on welded Aluminium/ Aluminium Alloy Wires**

Two Aluminium Alloy wires shall be welded as per the approved quality plan and shall be subjected to tensile load. The breaking strength of the welded joint of the wire shall not be less than the guaranteed breaking strength of individual strands.

28 **Ageing Test on Filler (if applicable)**

The test shall be done in accordance with test method specified in ASTM D566/ D2265 or relevant Indian/International standards. The specimen should not drop as a droplet when kept at a temperature 40 deg. C above designed maximum temperature of the conductor for 30 minutes. The temperature shall then be increase till one droplet drops and the temperature recorded.

29 **Minimum Conductivity Test on Aluminium Clad Core-Strands (if applicable)**

Resistivity test as per IEC 60468 shall be conducted to confirm minimum conductivity as per specification requirement.

30 **Glass Transition Temperature Test on Polymer Composite Core/ Core Strands (if applicable)**

Test shall be conducted as per ASTM B987. The minimum glass transition temperature shall be either (i) the temperature of core corresponding to the designed maximum temperature of the offered HTLS conductor + 35<sup>0</sup> C or (ii) minimum glass transition temperature as per ASTM B987 i.e. 180<sup>0</sup> C+ 25<sup>0</sup> C; Whichever is lower.

In case, the temperature of core corresponding to the designed maximum temperature of the offered HTLS conductor is more than the minimum glass transition temperature as per ASTM B987 i.e. more than 180<sup>0</sup> C, the test shall be conducted as per ASTM B987 & the minimum glass transition temperature shall be the temperature of core corresponding to the designed maximum temperature of the offered HTLS conductor+25<sup>0</sup> C.

31 **Flexural Strength Test on Polymer Composite Core/ Core Strands**

Supplier can carry out the test as per ASTM D4475. The flexural strength shall not be less than the value guaranteed in the GTP.

32 **Bending test on Composite Core (as Acceptance test)**

Bending test on composite core shall be performed as per ASTM B987/ B987M-20 on composite core samples taken from stranded conductor. For test after stranding the diameter of cylindrical mandrel shall be as following:

- 1) For high strength grade composite core: 60 times the diameter of composite core.
- 2) For Extra high strength grade composite core: 70 times the diameter of composite core.

33 **Chemical Analysis of Zinc**

Samples taken from the zinc ingots shall be chemically/ spectrographically analysed. The same shall be in conformity to the requirements stated in the Specification.

34 **Chemical Analysis of Aluminium/ Aluminium Alloy**

Samples taken from the Aluminium/ Aluminium Alloy shall be chemically/ spectrographically analysed. The same shall be in conformity to the particulars guaranteed by the bidder so as to meet the requirements stated in this Specification.

35 **Chemical Analysis of Core Strands (not applicable for Composite Core/ Core Strands)**

Samples taken from the core coils/ strands shall be chemically/ spectrographically analysed. The same shall be in conformity to the particulars guaranteed by the bidder so as to meet the requirements stated in this Specification.